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TEACHER'S RESOURCE BOOK

RENEWABLE SOURCES OF ENERGY

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The Energy Literacy Series

RENEWABLE SOURCES OF ENERGY

TEACHER'S RESOURCE BOOK

SRA

SCIENCE RESEARCH ASSOCIATES (CANADA) LIMITED
Toronto, Montreal, Chicago, Palo Alto, Sydney, Henley-on-Thames

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COVER DESIGN: Dykeman, Tabor & Reeves-Stevens, Ltd.

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ACKNOWLEDGMENTS

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Printing History
10 9 8 7 6 5 4 3 2 1 91 90 89 88 87 86 85 84 83 82

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PREFACE

"Because our society is geared to living from day to day, it is difficult to recognize the long-term significance of events that are happening now. Even on major issues, we expect immediate action from our leaders, and we generally limit our own participation to reading the headlines.

But, in the next twenty to fifty years, the world will undergo massive changes in its supply and use of energy. In order to cope, we will have to alter lifestyles and expectations. We must recognize, too, that the greatest changes will occur during our children's lifetimes, and beyond ours. We will be shirking our responsibility unless we do everything possible to prepare the next generation for these social changes.

Society must stop forming its opinions about energy from headlines only. We must learn, and teach, the facts and encourage the most careful analysis of the issues. Emotionalism can only deter society from effective action."

Marshall Williams

Marshall Williams is a director and past president of SEEDS, the nonprofit foundation he was instrumental in establishing in May 1976. The acronym SEEDS identifies both the organization—Society, Environment & Energy Development Studies Foundation—and its offspring, the curriculum project now reaching published form.

From its beginning, SEEDS has worked toward its primary goal—to encourage the development of an "energy-literate" society, a society concerned about and committed to the wise use of energy.

The first task undertaken was the coordination of available human and material resources for energy and environment education, with the objective of developing twelve levels of curriculum materials for elementary and secondary school use. To accomplish this task, sixty educators, teams of 5 working at each level, immersed themselves in the wide range of materials made available to them, sifting and organizing the topics and issues into meaningful units of classwork appropriate to students' level of growth and understanding. Then, 150 teachers, with prior in-service training, tried out the study modules with more than 4000 students during the 1978-79 school year. Concurrently, a formal evaluation of these pilot units was undertaken by a team of professors of education. This class-testing and evaluation, combined with information and reviews provided by educators and personnel from energy-related industries and government bodies, provided guidelines for additional teams of teachers who then revised the materials.

Throughout, with the involvement of educators, environmentalists, business people, industry consultants, and government representatives, we have tried to achieve the presentation of balanced and objective educational modules that will help young people develop informed views of energy and the environment and act on them.

Our first years have been challenging, exciting, and rewarding. While there are many individuals to whom we extend our appreciation for helping to maintain this sense of purpose, one individual stands out as deserving of special thanks. Dr. Marshall Williams has been a constant source of leadership, encouragement, and most of all, vision.

Robert Westbury
Executive Director
SEEDS Foundation

INTRODUCTION

The SEEDS Curriculum Project, produced and published by SRA, provides both student and teacher materials for a four- to six-week unit of study on energy-related concepts. It is designed to help teachers incorporate this topical material into their regular science/social studies curricula by providing a "guided discovery" approach suited to the students' level of growth and understanding.

Information on both the SEEDS Foundation and the history of the SEEDS Curriculum Project is given in the Preface. This Introduction outlines the organization of the curriculum materials.

The components for this Level include a Teacher's Resource Book with Professional Reference Guide and a 64-page Student Book.

The Teacher's Resource Book provides information and guidelines, organized in a sequence of chapters for presenting the topics and carrying out the experiments, discussions, and other investigations. A description of the key elements of each chapter follows.

STRUCTURE OF CHAPTERS

Each chapter begins with a summary of practical details, set out to assist the teacher in planning and preparation. Following this summary appear some or all of the sections entitled Teacher Background, Core, and Extension(s).

Summary ***Objectives*** The knowledge and process skill objectives appear at the beginning of each chapter.

Time Since the time allotted to science and social studies within the curriculum varies widely from district to district, we have indicated the probable time for each activity or experiment. The Core program will require four to six weeks, depending on how often you schedule science and social studies; the Extensions are not included in this estimate. Because of the nature of the topics and experiments, some activities may take longer than the usual time you allot to a lesson.

Vocabulary One aspect of "energy literacy" is the acquistion of the vocabulary with which to discuss concepts, topics, and issues. Of course, comprehension of the concepts is the ultimate goal, but the chapters themselves are designed to develop that comprehension.

The vocabulary lists are provided for your information and use at your discretion. It is preferable to provide a "handle" or name for a concept when the students themselves request it, having found new words necessary to describe the results of their experiments or the progress of their activities. However, the nature of the material sometimes requires that these words or definitions be introduced by the teacher. The vocabulary for each chapter is stated at the beginning of each chapter. The lists contain those words that the students will encounter in their books or on the Exercise Sheets. The main reference for placing words in the list has been science vocabulary at the grade 7-9 level being used in core science curricula. Other words not in this text but required by the nature of the program are, of course, included.

Upon seeing a vocabulary word, students may look it up in a dictionary or put the word in a notebook to be asked about in class. Text context, labelled diagrams, captions, and questions on Exercise Sheets reinforce vocabulary.

Materials The items listed include other components for the level whether for student or teacher use. Special materials, not usually found in classrooms, are also listed.

Teacher Background Where a major or new concept is introduced, some background information is provided to reduce the need for teacher preparation. It usually takes the form of a brief summary of the basic scientific or technical concepts developed in the chapter. This section does contain more information than that given in the Student Books.

Core This section provides a suggested procedure for the chapter—whether it's a teacher presentation, an experiment, or a discussion—to achieve the stated objectives. Built into the procedure are suggestions for the appropriate introduction or use of the other components noted under the heading, Materials.

Activities These are simple hands-on investigations of some of the basic concepts studied in this unit. They may be demonstrated by the teacher or carried out by the whole class. All materials are listed and should be readily available. Typical student responses are provided where useful.

Extensions This section provides a brief explanation or suggestion for one or more activities that will further develop the sub-topic and related science or social studies skills.

Exercise Sheets Grouped at the end of this Teacher's Resource Book are the Exercise Sheets which are designed to be used as black-line masters. On behalf of SEEDS Foundation, the copyright holder, SRA grants you, the teacher, the right to reproduce the Exercise Sheets for classroom use. They are numbered sequentially and include a key to the chapter number and level title.

Student Book The Student Book serves as a base of reference for the major topic presented in the level. It provides a focus of interest for some group or class discussions, and guidelines for experiments or activities. The illustrations, whether photographic or artwork, have been selected to help students visualize and comprehend the more technical, complex, or unfamiliar elements of their study. A glossary of the vocabulary listed in the Teacher's Resource Book has been included at the back of the Student Book. Italics are used within the Student Book to emphasize safety precautions and procedures.

Energy Literacy Objectives

The objectives, stated in terms of learning outcomes expected for the students, draw on energy-related concepts from the social sciences, the natural sciences, and the physical sciences.

CHAPTER	KNOWLEDGE	PROCESS SKILLS
1 *Renewable Sources of Energy*	• recall the definition of energy • recall the change in sources of energy through the centuries • give opinions about the role of renewables in our energy crisis	• formulate plans
2 *Solar Energy*	• recall previously-held views of the sun and compare them with modern views of the sun • recall facts about temperature and state of matter in the sun • explain how the sun works • define solar energy • explain how much energy the sun produces • express the amount of solar energy the earth receives • list advantages and disadvantages in capturing solar energy	• interpret diagrams • interpret charts • define the joule operationally
3 *Demonstrating Solar Energy*	• discuss problems with capturing the sun's energy • state the steps of a typical experiment • explain why experiments are done • become familiar with a radiometer • demonstrate that the angle of a source of radiant energy to the vanes of a radiometer affects the speed at which the vanes revolve • show that the materials of an experiment should be selected carefully • show that the absence of an element in an experiment can be as important as its presence • demonstrate that when the inside of a container is heated by the rays of the sun, the type of cover on the container affects the change in temperature • become familiar with the concept of room temperature • become familiar with the concept of controlling the variables in an experiment • become familiar with the idea that black surfaces absorb the sun's energy better than white surfaces • show that the interpretation of data affects the conclusions one makes • show that an experiment may cast light on questions not covered in the hypothesis • demonstrate that when a container is heated by a lightbulb placed outside it, the material inside the container affects the change of temperature	• formulate plans • set up an experiment from a written description • work with others to conduct a group experiment • follow a procedure carefully • make and record observations accurately • develop and state conclusions • give arguments to support conclusions • write up an experiment • construct and fill in a data chart • use data from a chart to make a bar graph • read temperatures from a thermometer • calculate a change in temperature • think how to set up a part of an experiment not explicitly described • make and record data on a more complicated observation chart • make a line graph from an observation chart and interpret the line graph
4 *Using Solar Energy*	• explain what is meant by the Greenhouse Effect • recognize that walls and floors absorb energy and radiate it back • recognize how houses are best situated on building sites • become familiar with how solar collectors work • describe the operation of active and passive heating systems • explain how photovoltaic collectors work and how silicon cells are made • state some of the uses of photovoltaic collectors • describe how silicon cells turn the sun's energy into electricity	• read and interpret diagrams • apply discovered knowledge • calculate angles
5 *Biomass Energy*	• recognize how plants turn the sun's energy into chemical bonds • recognize what biomass is and why it is essential for human life	• read and interpret diagrams • apply discovered knowledge
6 *Demonstrating Biomass Energy*	• show the importance of a control in an experiment • use elementary logic to reach a conclusion about what a substance could be • demonstrate that oxygen helps wood to burn • demonstrate that an aquatic plant (like the elodea plant) exposed to sunlight gives off oxygen • observe and become familiar with dry, or destructive, distillation	• set up an experiment with careful attention to a control • use logic to interpret observations • set up an experiment from a written description • work with others to conduct a group experiment • follow a procedure carefully • make and record observations accurately • develop and state conclusions

CHAPTER	KNOWLEDGE	PROCESS SKILLS
6 *(continued)*	• recognize the fuels and by-products that can be obtained from biomass • become familiar with some characteristics of charcoal, tar, alcohol, and methane • demonstrate that energy is stored in biomass, and that the stored energy can be released by burning the biomass • demonstrate that the energy released from burning biomass can be used to raise the temperature of water	• give arguments to support conclusions • write up an experiment • read temperatures from a thermometer • construct and fill in a data chart • calculate a change in temperature • use characteristics of substances to identify them • write up an experiment with a five-part conclusion • interpret diagrams • interpret charts • define the joule operationally • make a chart of conclusions • calculate the amount of energy needed to raise the temperature of a given amount of water a given number of degrees • use a balance to find mass in grams • measure water in millilitres • measure and record the temperature of water • calculate an amount of mass converted to heat energy • calculate the amount of heat energy, in joules, given off by burning biomass
7 ***Using Biomass Energy***	• state the fuels that can be obtained from biomass • recognize how fuels can be obtained from biomass • explain how biomass from wastes can be used • recognize how biomass is grown for fuel • describe some of the uses of biomass fuels • investigate the consequences of growing biomass for fuel	• apply discovered knowledge
8 ***Wind Energy***	• recall that the earth turns from west to east • recognize that warm air rises and has low pressure • recognize that cool air falls and has high pressure • recognize that high-pressure air moves toward low-pressure air • show that uneven heating of the earth's surface by the sun causes wind	• do a thought experiment • make drawings from written instructions
9 ***Demonstrating Wind Energy***	• become familiar with some of the components of a horizontal-axis windmill • demonstrate that the angles of the blades of a windmill affect the speed at which the vanes of the windmill revolve • recognize that wind has kinetic energy • recognize some of the relationships among kinetic energy, mechanical energy, and potential energy • find out how much energy (in joules) a model windmill can generate • demonstrate that it takes one joule to lift one hundred grams one metre • recognize that power is energy divided by time • recognize that power (in watts) is energy (in joules) divided by time (in seconds) • find out how much power (in watts) a model windmill can generate • demonstrate that a windmill can be used to store energy	• control variables in an experiment • formulate plans • build a model • use a protractor to measure the angle of blades • count and record the number of revolutions a blade makes in one minute • make an observation chart • make a line graph from a chart • use characteristics of substances to identify them • write up an experiment with a five-part conclusion • equalize the height above base level of two objects
10 ***Using Wind Energy***	• list four types of horizontal-axis windmills • list three types of vertical-axis windmills • state the parts of a windmill that make electricity • state three types of energy storage used by windmills • recognize that, during the day, warm air rises and blows from land out over water and cool air blows across water and onto land • recognize that, at night, warm air blows from land over water and cool air falls onto land • recognize that, during the day, mountain slopes, because of their angle to the sun's rays, heat up faster than valleys so that cool air flows up mountain slopes from valleys • recognize that, at night, valleys cool more slowly than mountain slopes so that cool air flows down mountains into valleys • become familiar with an anemometer • become familiar with the Beaufort scale of winds • rate windspeeds as suitable or unsuitable for windmills • investigate the environmental consequences of using wind energy	• apply ideas gained from doing experiments in order to understand written material • design an experiment • consolidate insights gained from previous experiments • do a thought experiment independently • make and label diagrams • read instructions and make an anemometer • read an anemometer • read a wind scale • compare a wind scale with a wind-speed rating chart
11 ***The Future of Renewable Energy Sources***	• recall the information presented in this unit	• apply discovered knowledge

Chapter 1

Renewable Sources of Energy

OBJECTIVES

Knowledge

- **recall the definition of energy**
- **recall the change in sources of energy through the centuries**
- **give opinions about the role of renewables in our energy crisis**

Process Skills

- **formulate plans**

Vocabulary

energy

TEACHER BACKGROUND

Flat plate collectors for space and water heating are perhaps one of the best understood and practical applications of solar energy today. There are now hundreds of solar-heated houses in North America, with hundreds more currently being designed and built.

Unlike a site chosen for the sun, which shines in sufficient quantity everywhere in Canada, the site chosen for wind is very critical. Whole regions which have insufficient wind for economic harnessing may contain specific sites that are appropriate. When a good site is chosen, wind has a potential for both small-scale (home or cottage) and large-scale (community) applications, especially in remote areas.

Biomass, material that is or once was living, is perhaps the most complex of the renewable energy sources. This is because the energy sources, the harnessing technologies, and the energy output are all extremely varied. Renewable biomass energy sources include animal and agricultural wastes, forestry wastes, and crops which have been grown specifically as an energy source. Using various technologies (direct combustion, pyrolysis, anerobic digestion, etc.) various forms of energy can be extracted, such as heat, steam, electricity, methane, methanol, and so on.

Wood burning for space heating is the most extensive and practical use of renewable biomass energy today. Modern (and some not so modern) wood-burning stoves and furnaces can be economical, efficient, and convenient.

By digesting biomass such as animal or crop wastes without oxygen (anaerobically), methane is produced. Methane can be used to supply heat, generate electricity, or operate internal combustion engines.

CORE

Student Book pages 5-9

At the beginning of this unit, you should ask the students to begin collecting newspaper and magazine articles on the following topics: wood energy, solar power, wind and water power, and biomass (garbage energy). Each student can be asked to bring in two articles a week as part of class requirements. You should also be on the look-out for appropriate articles.

This opening chapter is designed to introduce students to renewable sources of energy, to stimulate them to think about renewables as a replacement for more conventional energy sources and why they think this would be beneficial or harmful both to themselves and their environment.

Encourage students to see both sides of the picture. For example, windmills do not pollute the air with particulate matter, but they do cause a certain amount of noise pollution.

EXTENSION

Social Awareness Why should we learn about renewable sources of energy? At this point, students will know only what they have read about renewable sources of energy. Many will have a very positive, idealistic view of renewables. It might be useful to have the class make a chalkboard list of the positive and negative aspects of renewables, to be discussed again once the unit has been taught. Encourage the students to think of as many points both for and against renewables under these headings: Can my family use solar power in our home? Can windmills be useful for our community? Would a biomass plant be a useful part of our community? Should every home have a wood stove?

Chapter 2

Solar Energy

OBJECTIVES

Knowledge

- **recall previously-held views of the sun and compare them with modern views of the sun**
- **recall facts about temperature and state of matter in the sun**
- **explain how the sun works**
- **define solar energy**
- **explain how much energy the sun produces**
- **express the amount of solar energy the earth receives**
- **list advantages and disadvantages in capturing solar energy**

Process Skills

- **interpret diagrams**
- **interpret charts**
- **define the joule operationally**

Vocabulary
chromosphere, convective zone, core, corona, electrons, gas, helium, hydrogen, interior, joule, kilowatt, kilowatt hour, liquid, megajoule, nuclei, photosphere, plasma, proton reaction, radiative, rhodium, silicon cell, solar collector, solar energy, solid, transition zone, unstable helium, watt

Materials
Exercise Sheet 1

TEACHER BACKGROUND

Experimentation is the lifeblood of science, and much of the material in this program is devoted to it. However, all experimentation is done against a background of knowledge and belief. It is what we know, think we know, or think might be true, that we test by experimentation. In this spirit, students are asked to assimilate a body of knowledge by reading. They are not to regard this information as absolute knowledge, but rather as a well-integrated body of hypotheses, each of which can be tested by experimentation.

CORE

Student Book pages 10-13

The reading material on these pages of the Student Book provides a body of hypotheses. These hypotheses have been stated in a simple manner. Any ideas that are difficult for average students have been put into diagrams. Encourage students to draw diagrams in their own notebooks, in writing up experiments, and in working with the reproducible Exercise Sheets found at the end of this Teacher Resource Book.

Exercise Sheet 1

Students who develop special interests may be assigned one-page essays. Question 20 of Exercise Sheet 1 provides a list of such questions. This list also provides ideas for teacher-led class discussions.

Exercise Sheet 1 may be reproduced and given out to students as a way of reinforcing and consolidating their understanding of Student Book pages 10 to 13. Thereafter, there are options.

1. Take up the work and use it as a basis for evaluating student performance.
2. Discuss the questions and answers in class.
3. Combine 1 and 2, above.

4. Take up and evaluate all but question 20. Have those who picked a given part of question 20 form a group, prepare a group report, and present it to the class. One or two members of the group would be responsible for drawing on the chalkboard any diagrams necessary to class understanding of the report. This activity reinforces the modern notion that scientists work in teams and have to prepare both written and verbal reports on their work.

EXTENSION

Social Awareness Why should we try to capture the energy of the sun? You might like to divide your class into two groups to discuss this question. To narrow the topic somewhat, you could have the groups consider using the energy of the sun to heat their homes whether single-family dwellings, rowhouses, or apartments. One group could consider the positive aspects (the sun's energy is free; it is a nonpolluting source of energy; it is considered a renewable source of energy) and the other group could consider the negative aspects (the sun's energy is inconstant; there is less energy from the sun in the winter when we need it the most; a great deal of expensive technology is needed to make use of the sun's energy efficiently). A chalkboard list of the points mentioned could be used to keep the groups from repeating themselves. When both sides have finished making their points, the class could vote on which side presented a better case.

Chapter 3

Demonstrating Solar Energy

OBJECTIVES

Knowledge

- **discuss problems with capturing the sun's energy**
- **state the steps of a typical experiment**
- **explain why experiments are done**
- **become familiar with a radiometer**
- **demonstrate that the angle of a source of radiant energy to the vanes of a radiometer affects the speed at which the vanes revolve**
- **show that the materials of an experiment should be selected carefully**
- **show that the absence of an element in an experiment can be as important as its presence**
- **demonstrate that when the inside of a container is heated by the rays of the sun, the type of cover on the container affects the change in temperature**
- **become familiar with the concept of room temperature**
- **become familiar with the concept of controlling the variables in an experiment**
- **become familiar with the idea that black surfaces absorb the sun's energy better than white surfaces**
- **show that the interpretation of data affects the conclusions one makes**
- **show that an experiment may cast light on questions not covered in the hypothesis**
- **demonstrate that when a container is heated by a lightbulb placed outside it, the material inside the container affects the change of temperature**

Process Skills

- **formulate plans**
- **set up an experiment from a written description**
- **work with others to conduct a group experiment**
- **follow a procedure carefully**
- **make and record observations accurately**
- **develop and state conclusions**
- **give arguments to support conclusions**
- **write up an experiment**
- **construct and fill in a data chart**
- **use data from a chart to make a bar graph**
- **read temperatures from a thermometer**
- **calculate a change in temperature**
- **think how to set up a part of an experiment not explicitly described**
- **make and record data on a more complicated observation chart**
- **make a line graph from an observation chart and interpret the line graph**

Vocabulary
angle, cellophane, conclusion, confirm, dashed line, dotted line, experiment, hypothesis, materials, observation, observer, precise, procedure, protractor, radiometer, recorder, reject, revolve, solid line, Styrofoam, thermometer, translucent

Materials
Student Materials—see Student Book pages 15, 18, 21

CORE

Student Book pages 14-17

Experiment 1 (Set-up—5 min; Duration—20 min). Experiment 1 is well worth the time it takes to set up properly. Although the experiment may be performed by one group as a demonstration for the rest of the class, it is best to divide the class into groups. Student Book page 16 shows a typical group. In the event that the classroom does not have a large, easily seen clock, each group will need a stopwatch. You may wish to turn off the room lights and draw the sun curtains at the beginning of the Procedure.

Each group must learn to coordinate its activities so that the data are gathered completely and accurately. If this is done systematically, all should go well. Some groups may need to go back and repeat a particular part of the experiment. Only in extreme cases would it be necessary to repeat the entire experiment.

Make certain each group lets the vanes of the radiometer stop revolving before beginning a reading at a new angle.

The Review of Experiment 1 may be used as a testing device or as a guide to writing up the experiment. In either case, it is a good idea for each student to keep a notebook for experiments and to write up his or her own results.

In this experiment, special attention is paid to the conclusion. Emphasize that the conclusion is to confirm or reject the hypothesis and give reasons. The reasons may be expressed in many ways. The conclusion should be stated in the same language as the hypothesis. Discourage conclusions not tested by the experiment such as: The best angle for the sun is. . . .

Student Book page 17

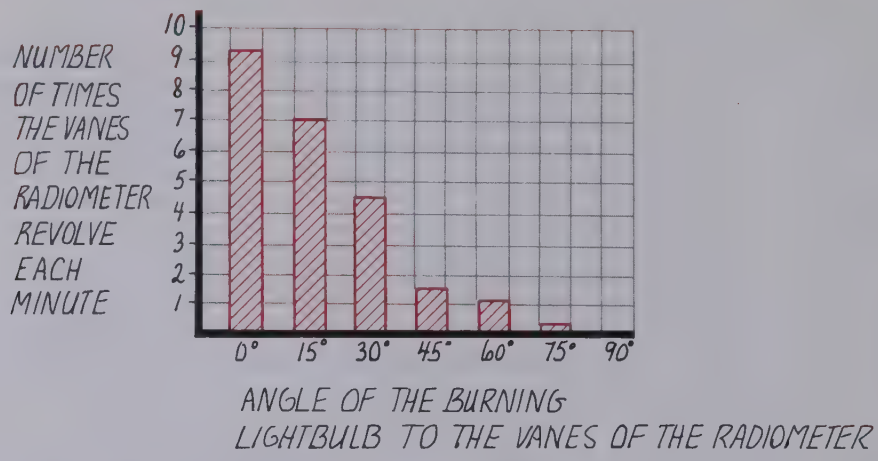
Answers

1. *(See Student Book page 14.)*
2. *(See Student Book page 14.)*
3. **HYPOTHESIS** *(See Student Book page 15.)*
   MATERIALS *(See Student Book page 15.)*
   PROCEDURE *(See Student Book page 15.)*
   OBSERVATION

POSITION	ANGLE	REVOLUTIONS
(a)	90°	0
(b)	75°	0.25
(c)	60°	1.00
(d)	45°	1.50
(e)	30°	4.25
(f)	15°	7.00
(g)	0°	9.25

CONCLUSION I confirm the hypothesis because my observations indicated that the number of revolutions per minute of the vanes of the radiometer varied with the angle of the lightbulb. When the light source was at an angle of 0°, the revolutions per minute were greatest. When the light source was at an angle of 90°, the revolutions per minute were least. *(Note: Here the light source is at 0° for maximum effect. This is 0° to the surface on which the radiometer is sitting. However, 0° to the surface on which the radiometer is sitting is 90° to the vanes of the radiometer.)*

4.



5. *a.* The Observation Chart has more precise data than the Bar Graph.
   b. The Bar Graph is more easily read.

Student Book pages 18-20

Experiment 2 (Set-up—15 min; Duration—25 min). Experiment 2 focuses on the materials that are used in it. Student Book page 18 explains the materials in detail. (Note: If there is insufficient sunshine, use a 150-W bulb attached to a utility stand.) After each group has set up the experiment and is ready to make observations, you might stop and discuss the materials and how they relate to the hypothesis. The focus of such a discussion would be on how the particular materials chosen might help one to test the hypothesis. Far-fetched questions, while nonsensical to some students, are illuminating to others. For instance, why not use a ball-point pen instead of a thermometer? Of particular importance is the question of the covers for the cups. The difference between clear cellophane and translucent paper should be discussed, as well as the absence of a cover on one cup. With a sophisticated class, the notion of a control in an experiment might be discussed. Time spent on these topics will be rewarded later when the Greenhouse Effect is discussed.

Handling the materials is also important. The bottom end of the thermometer should go inside the cup. Also the thermometers must be handled carefully so that they do not break. You may wish to place the thermometers through the stoppers, yourself, prior to the experiment. For safe passage of the thermometers, use either Vaseline or stopcock grease to lubricate both the thermometer and the hole in the stopper. This helps to eliminate broken thermometers. If you feel the students can perform this step themselves, demonstrate for them the correct method of inserting the thermometers—for safety reasons. Finally, caution the students not to look directly into the sun or a reflection of the sun, to avoid the risk of permanent eye damage.

The Review of Experiment 2 may be used as a listing device or as a guide to writing up the experiment. As the focus of this experiment is on the materials, this review concentrates on why certain materials were used, and on different ways of recording results of experiments.

Student Book page 20

Answers

1. *(See Student Book page 14.)*
2. *a.* Styrofoam does not conduct heat easily, so it will keep heat in the cups.
   b. Elastic bands are easier to manipulate than string when holding materials on a round surface.

c. Clamps allow the cups to be adjusted to the correct angle as well as to be attached to the stand.
d. Two uses for the stoppers would be to hold the thermometer in place and to stop the heat from escaping the cup.
e. In this experiment, we are measuring heat, whereas in Experiment 1, we measured the intensity of certain light angles.
f. The cups are clamped to a stand so that control can be applied to the angle of the light rays. As well, clamping provides an added safety feature to prevent the thermometers from being broken.
g. If there were insufficient sunshine, a 150-W lightbulb would be a suitable substitute for the sun as a source of energy.
h. It is covered with white paper so that it will have a translucent cover which will let only some of the light rays through.
i. It is covered with clear cellophane so that it will have a cover which will allow all the light rays into the cup (and intensify the heat).
j. Without introducing the uncovered cup, we would not have as accurate a scale with which to measure the true effect of the covers. *(Note: The uncovered cup is the control.)*
k. Working with glass can be very dangerous unless proper care is taken. One should always use a lubricant such as Vaseline or stopcock grease to reduce the friction and allow for easy passage of the thermometer through the stopper.

When we deal with the sun, we should be aware that the sun's rays can seriously damage the retinas of our eyes, permanently. For this reason, we should never look directly into the sun, nor should we look at the reflected light of the sun.

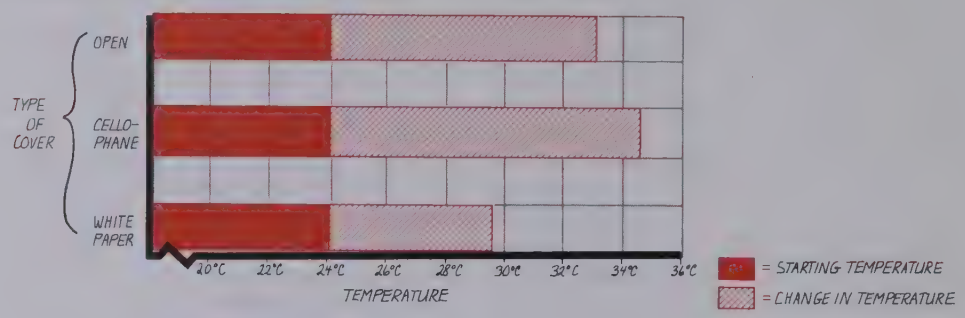
3. **HYPOTHESIS** *(See Student Book page 18.)*
MATERIALS *(See Student Book page 18.)*
PROCEDURE *(See Student Book page 19.)*
OBSERVATION

OBSERVATION CHART

TYPE OF COVER	STARTING TEMP. (°C)	FINAL TEMP. (°C)	CHANGE IN TEMP. (°C)
OPEN	24°C	33°C	9°C
CLEAR CELLOPHANE	24°C	34.5°C	10.5°C
WHITE PAPER	24°C	29.5°C	5.5°C

CONCLUSION I confirm the hypothesis that different covers affect the change in temperature in a Styrofoam cup because the clear cellophane cover intensified the natural change in temperature, whereas the paper cover decreased the change in temperature.

4. Typical Observation Bar Graph



a. (Answers will vary.)
b. The Observation Chart has more precise data.
c. It is easier to read the change in temperature on the Observation Chart, but the Bar Graph illustrates the conclusion of the experiment more dramatically.

Student Book pages 21-23

Experiment 3 (Set-up—15 min; Duration—35 min). Experiment 3 reinforces the importance of the materials in an experiment (learned in Experiment 2) and the importance of the conclusion (learned in Experiment 1).

You may wish to have students use a stopwatch or a timer since they will be keeping track of details for specific amounts of time. As for Experiment 2, it is important to warn students about the hazard involved in forcing glass thermometers through stoppers without the use of Vaseline or stopcock grease or a similar lubricant.

Although the phrase *controlling the variables* does not occur in the Student Book, this experiment explores that concept. First, the procedure does not instruct the students on how to position the lightbulb. Questions 4, 5, and 6 of the Review explore the water, cans, and light as variables. The water and gravel should be at room temperature. Each can should be the same distance from the light. Second, the Review explores why the cans should be the same color, and why black is a good choice. Third, the Observation Chart on page 21 of the Student Book indicates that the bulb is to be turned off after 15 min. This changes one of the variables.

After the students have made a line graph from the data on the chart, they may think about interpreting data. The questions asked in question 9 on Student Book page 23 should help them write better conclusions. Some students may feel that the hypothesis is about a rise in temperature and make conclusions only about that. Others may realize that the hypothesis is about any change in temperature, whatsoever. There should be two conclusions, one about the time the light is on, and another about the time after it is turned off.

Student Book pages 22-23

Answers

1. *(See Student Book page 14.)*
2. All three cans should be the same size so that the amount of space needed to be heated is the same. If one can were very large, it would take much longer to raise the temperature and thus reduce the "control" of the experiment.
3. The three cans should be the same color so that the materials will be the same. In Experiment 2, we found that materials could change experimental results. If one can were white, the radiant rays would be reflected rather than be absorbed and thus severly reduce "control" in the experiment.

The black car would be hotter.

The players keep cooler wearing white.

The cans are painted black so that the maximum amount of heat can be absorbed.

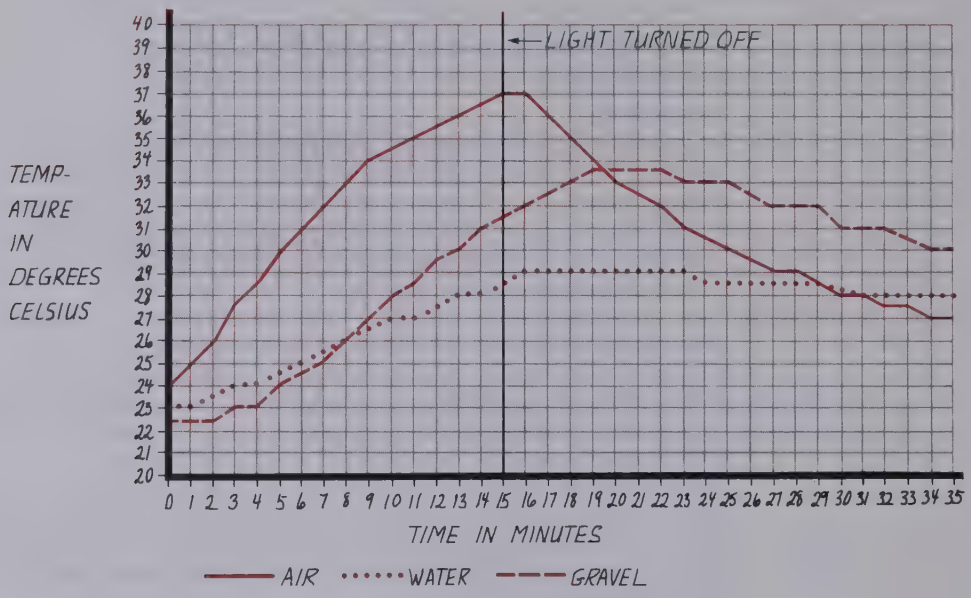
(Note: If students find these questions difficult, perhaps a list of "facts" such as the color black absorbing heat, white reflecting it, and the larger the space, the more heat energy being taken to raise the temperature one degree Celsius, and so on, could be reviewed with them.)

4. The closer the temperature of the water is to the air in the room, the more accurate will be the results.
5. The three cans should be the same distance from the light so that they can all absorb equal amounts of heat. If one were farther away, the "control" of the results would be severely reduced.
6. I mounted the lightbulb on a clamp and attached it to a utility stand. The lightbulb could have been suspended from an overhead socket, or it could have been clamped to a table.
7. All three starting temperatures are not the same. One possible explanation could be that there is a slight 1°C variance in many thermometers. Since the variance was not great, the effect on the test results shouldn't be greatly affected. Also, water from a tap may vary due to the length of time it has been standing in the pipes.
8. *(See answer 9.)*
9. **HYPOTHESIS** *(See Student Book page 21.)*
   MATERIALS *(See Student Book page 21.)*
   PROCEDURE *(See Student Book page 21.)*
   OBSERVATION

OBSERVATION CHART

TIME	TEMPERATURE °C			TIME	TEMPERATURE °C			TIME	TEMPERATURE °C		
MINUTES	AIR	WATER	GRAVEL	MINUTES	AIR	WATER	GRAVEL	MINUTES	AIR	WATER	GRAVEL
0	24	23	22.5	12	35.5	27.5	29.5	24	30.5	28.5	33
1	25	23	22.5	13	36	28	30	25	30	28.5	33
2	26	23.5	22.5	14	36.5	28	31	26	29.5	28.5	32.5
3	27.5	24	23	15	37	28.5	31.5	27	29	28.5	32
4	28.5	24	23	16	37	29	32	28	29	28.5	32
5	30	24.5	24	17	36	29	32.5	29	28.5	28.5	31.5
6	31	25	24.5	18	35	29	33	30	28	28	31
7	32	25.5	25	19	34	29	33.5	31	28	28	31
8	33	26	26	20	33	29	33.5	32	27.5	28	31
9	34	26.5	27	21	32.5	29	33.5	33	27.5	28	30.5
10	34.5	27	28	22	32	29	33.5	34	27	28	30
11	35	27	28.5	23	31	29	33	35	27	28	30

REMEMBER TO TURN THE LAMP OFF AFTER 15 MIN



10. **CONCLUSION** I confirm the hypothesis that the material inside the container affects the change in temperature when heat is applied from the outside. During the first 15 min when the light was on, the change in temperature was most evident in the can of air, followed by the can of gravel, and finally, at a much more gradual change, the can of water. After the light was turned off, the temperature of the can of air immediately stopped rising and then began to fall almost as steeply as it rose. The temperature of the can of gravel continued to rise for another 5 min before levelling off and slowly beginning to fall. The temperature of the can of water rose 1°C and then remained virtually constant for the next 20 min.

    EXTENDED CONCLUSIONS Water retains heat at a constant temperature longer than air and more readily than gravel.

    Gravel continues to radiate heat after the source is removed.

    Air absorbs heat more rapidly than water or gravel, but does not retain it very well.

    (Note: Additional conclusions may result following your direction of the students.)

EXTENSIONS

Encourage students to speculate about what would happen if different materials were used in Experiment 2. Different colors of cellophane, different numbers of layers of the same color, different kinds of material (fabric, metal, etc.), and so on can be used.

Interested students could perform an experiment similar to Experiment 3 by using one absorptive substance (water or gravel or air) but using differently colored cans. Students will soon see that the darker the color, the greater the rate of absorption.

Chapter 4

Using Solar Energy

OBJECTIVES

Knowledge

- **explain what is meant by the Greenhouse Effect**
- **recognize that walls and floors absorb energy and radiate it back**
- **recognize how houses are best situated on building sites**
- **become familiar with how solar collectors work**
- **describe the operation of active and passive heating systems**
- **explain how photovoltaic collectors work and how silicon cells are made**
- **state some of the uses of photovoltaic collectors**
- **describe how silicon cells turn the sun's energy into electricity**

Process Skills

- **read and interpret diagrams**
- **apply discovered knowledge**
- **calculate angles**

Vocabulary
active, boron, deciduous, evergreen, infrared, insulation, latitude, opaque, passive, photovoltaic, radiate, reflect, silicon, solar collector, thermostat

Materials
Exercise Sheet 2

CORE

Student Book pages 24-28

Having done Experiments 1, 2, and 3, students should realize that the sun gives off energy that can be captured. Experiment 1 explores the angle of a source of radiant energy to the surface of a solar collector. Student Book pages 24 and 25 show students how to calculate the best angle of south-facing greenhouse windows. Students should be encouraged to work through these pages with pencil and paper or with a calculator. A central idea of this section is that the best angle of a solar collector to the sun is 90°. Some students may recall that in Experiment 1 the vanes of the radiometer turned fastest when the lightbulb was at 0°. Those who find this a contradiction should be encouraged to work through the calculations at the end of page 25. The lightbulb is analogous to the sun. If the angle of its light to the table is 0°, the best angle of the radiometer's vanes to the table will be 90°. This is the angle the vanes have to the table when the radiometer is standing upright.

Experiment 2 deals with the best covering for a container to capture the sun's energy. Student Book page 26 gives a more formal explanation of why a transparent cover is best. This leads to an operational definition of the Greenhouse Effect.

Student Book page 26 also deals with the fact that the walls and floors absorb energy from the sun during the day and release heat energy at night. This reinforces the work in Experiment 3. Students might be asked to speculate about what material would be best for the back wall and floor of a greenhouse.

It should be emphasized that the solar systems on Student Book pages 24 to 28 use principles developed in Experiments 1, 2, and 3.

Student Book pages 29-30

The material on these pages will aid students to make the connection between solar energy and biomass energy, to be encountered in the next chapter.

Exercise Sheet 2

Exercise Sheet 2 provides material for evaluation and class discussion. In working with this material, students should be encouraged to draw diagrams wherever possible.

EXTENSION

Have students write reports or one-page essays. Topics might include the following:

- What Is the Greenhouse Effect?
- How Do Photovoltaic Collectors Work?
- How Can the Sun Heat Homes?

Chapter 5

Biomass Energy

OBJECTIVES

Knowledge

- **recognize how plants turn the sun's energy into chemical bonds**
- **recognize what biomass is and why it is essential for human life**

Process Skills

- **read and interpret diagrams**
- **apply discovered knowledge**

Vocabulary

biomass, carbohydrate, carbon, carbon dioxide, cell, cellulose, digest, electricity, fat, hydrogen, molecule, oxidize, oxygen, photosynthesis, protein, starch, sugar

CORE

Student Book pages 31-32

The material on Student Book pages 31 and 32 deals with collectors that change solar energy not into heat energy, but into electrical and chemical energy. Here, green plants are treated as solar collectors. This allows photosynthesis to be taught from a unique point of view, and provides a smooth transition from solar energy to biomass energy. The overall principle of Chapter 5 is that biomass energy comes ultimately from the sun.

The chemistry on these pages is very elementary. The analysis leans heavily on what the words mean, and examples have been chosen with this kind of analysis in mind.

EXTENSIONS

Students could, in groups, prepare and present illustrated class reports on topics such as the following:

- Are Plants Solar Collectors?
- What Is Photosynthesis?
- What Is Biomass?
- Why Are Plants Important to Us?

Some students may want to do a further experiment based on the information on Student Book page 32 that starch is a product of photosynthesis. Parts of a plant leaf can be masked. The plant can be exposed to sunlight. Iodine can be used to test for the presence of starch in the leaf. Such an experiment would have a built-in control.

Social Awareness What would a world without plants be like? This question could be assigned as a homework project. Students could write several short paragraphs in the form of an essay, a pamphlet, a poster, a television commercial, and so on. They should use whichever form they choose to convince their audience of the positive aspects of the question (no pollen for allergy sufferers; no leaves to rake; nothing to remember to water) or to warn about the negative aspects (no life; no food; no oxygen; no beauty). The form the students choose will, of course, dictate its own arrangement of arguments.

When all students have completed their work, the class as a whole can decide which presentation was most effective and why. Since a world without plants is unthinkable, this exercise might lead the students to realize how often the true meaning of a message can be hidden by the way in which it is presented.

Chapter 6

Demonstrating Biomass Energy

OBJECTIVES

Knowledge

- show the importance of a control in an experiment
- use elementary logic to reach a conclusion about what a substance could be
- demonstrate that oxygen helps wood to burn
- demonstrate that an aquatic plant (like the elodea plant) exposed to sunlight gives off oxygen
- observe and become familiar with dry, or destructive, distillation
- recognize the fuels and by-products that can be obtained from biomass
- become familiar with some characteristics of charcoal, tar, alcohol, and methane
- demonstate that energy is stored in biomass, and that the stored energy can be released by burning the biomass
- demonstrate that the energy released from burning biomass can be used to raise the temperature of water

Process Skills

- set up an experiment with careful attention to a control
- use logic to interpret observations
- set up an experiment from a written description
- work with others to conduct a group experiment
- follow a procedure carefully
- make and record observations accurately
- develop and state conclusions
- give arguments to support conclusions
- write up an experiment
- read temperatures from a thermometer
- construct and fill in a data chart
- calculate a change in temperature
- use characteristics of substances to identify them
- write up an experiment with a five-part conclusion
- interpret diagrams
- interpret charts
- define the joule operationally
- make a chart of conclusions
- calculate the amount of energy needed to raise the temperature of a given amount of water a given number of degrees
- use a balance to find mass in grams
- measure water in millilitres
- measure and record the temperature of water
- calculate an amount of mass converted to heat energy
- calculate the amount of heat energy, in joules, given off by burning biomass

Vocabulary
alcohol, aquarium, aquatic, charcoal, distillation, elodea, experimentation, graduated cylinder, joule, logic, methane, tar

Materials
Student Materials—see Student Book pages 33, 36, 39

TEACHER BACKGROUND

Dry distillation is a type of pyrolysis in which there is very little ambient oxygen. This results in the creation of charcoal, a product not associated with types of pyrolysis in which there is a free flow of air or oxygen.

CORE

Student Book pages 33-42

Experiment 4 emphasizes only the beginning and end of photosynthesis as a way of testing the hypotheses that the plant is a solar collector and that it gives off oxygen essential to human life and to burning of fuels. Experiment 5 explores what fuels are produced by biomass. Experiment 6 explores the energy content of raw biomass. These latter two experiments, therefore, deal more directly with plants' internal storage of the sun's energy.

Student Book pages 33-35

Experiment 4 (Set-up—25 min; Duration—48 h). Although the Student Book does not use the word *control*, Experiment 4 has a prominent control. Emphasis should be placed on the idea that if we were merely to place an elodea in sunlight, without placing another in darkness, we would not be able to say that the sunlight was a factor in producing oxygen.

After Chapter 5, students should be familiar with photosynthesis. Experiment 4 isolates the beginning and end of the process of photosynthesis. Caution students that their conclusion may well be that the plant gives off oxygen but that they could not conclude from this experiment alone that photosynthesis is taking place.

If you feel students will have any difficulty following the procedure as outlined in setting up the experiment, you could have them use the following alternate procedure:

1. Place the elodea plant in a glass funnel and lower it carefully into a beaker with enough water to cover the funnel's narrow tip to at least 1 cm.
2. Fill a test tube to the top with water. Place your finger tightly over the end to prevent water or air getting in.
3. Carefully lower the test tube into the water and over the funnel's tip before removing your finger.

On page 34 of the Student Book, pairs of students will be working with a lighter or matches. If you feel students are not properly familiar with fire safety rules, you might wish to review them with them. You might also choose to do this stage of the experiment yourself for each pair of students.

The solution to the riddle on page 34 of the Student Book is "Its temperature is too low."

Student Book page 35

Answers

1. *(See Student Book page 14.)*
2. **HYPOTHESIS** *(See Student Book page 33.)*
   MATERIALS *(See Student Book page 33.)*
   PROCEDURE *(See Student Book pages 33-34.)*

   (Note: Students may add that leaving the beaker in bright sunlight for more than 24 h—48 or 72—would produce even better results.)

   OBSERVATION There appears to be a gas in both test tubes which has replaced the water. *(Note: Students may report that there is much more gas in the one exposed to sunlight.)*

   When the toothpick is put into the test tube which had been over the plant exposed to sunlight, the toothpick burst into flame.

   The toothpick did not burst into flame after being put into the other test tube.

CONCLUSION I confirm the hypothesis because the glowing splint burst into flame which is characteristic of smoldering materials when exposed to oxygen.

3. It was necessary to put another plant in darkness for control.
4. Glass does not allow the gases to escape into the surrounding water.
5. It is important that the funnels be smaller in diameter than the beakers so that the funnels fit.
6. If the funnels were longer than the beakers' height, the air pressure would drive the water down to the top of the beakers.
7. The test tubes captured the gases being given off by the plants.
8. Since water is heavier than air, it drove out all the air in the test tube so that any air that might appear later must have come from the plant.
9. If there were bubbles, the oxygen would not be pure and the control would be lost.
10. There appeared to be a gas in the test tube.
11. There appeared to be gas in the test tube similar to the other.
12. Nothing happened because there was no pure oxygen present.
13. Oxygen caused the smoldering material to burst into flame.
14. I was able to confirm the hypothesis because oxygen was present in the test tube exposed to sunlight and not in the test tube in the "control" beaker.

Logic is a difficult concept to define. If students are having difficulty with Student Book page 35, you might like to lead them through a few simple samples of logical reasoning.

Student Book pages 36-38

Experiment 5 (Set-up—15 min; Duration—25 min). Experiment 5 is a teacher-demonstrated experiment in which the conclusion is anything but obvious. The experiment demonstrates that ordinary wood can be broken down into a number of products. To determine what those products are requires careful observation, thought, and perhaps further experimentation.

Several safety precautions should be practiced in this teacher-demonstrated experiment, including the following:

1. All students observing the experiment should wear safety goggles.
2. Students should be familiar with safety procedures in the laboratory and fire extinguishers or fire blankets should be present in the laboratory.
3. As in Experiment 2, a lubricant should be used to fit glass into stoppers.
4. The use of safety glass is essential while heating any stoppered test tube or flask.
5. Caution should be taken so not too intense a degree of heat is used (popping corks, breaking glass, etc.).

The list of characteristics on Student Book page 37 should help students to decide which products have been created in the experiment. The tar is actually wood tar, not the petroleum tar usually used to pave highways. The characteristics listed in the Student Book are common to both kinds of tar. The comment on methane, on Student book page 37, with some discussion, should help student to distinguish methane gas from oxygen which is also colorless and odorless. While oxygen supports combustion, methane is *very* flammable.

How students reach their conclusions is as important as the conclusions they reach. It may be better to err on the side of being too rigorous and reject parts of the hypothesis than to be overly credulous and confirm something not really justified by the observations. For instance, the experiment, as described, does not adequately provide for the testing of water or alcohol. A liquid is seen as a distillate but it is unclear as to *what* it is. Student Book page 38 calls for a chart on how the conclusions have been reached. This is intended to reflect the fact that once observations are recorded, their interpretation may require reasoning, additional research, or even further experimentation.

Student Book page 38

Answers

1. *(See Student Book page 14.)*
2. **HYPOTHESIS** *(See Student Book page 36.)*
   MATERIALS *(See Student Book page 36.)*
   PROCEDURE *(See Student Book page 36.)*
   OBSERVATION Chips began to char and "smoke" began to fill Test Tube 1.

   The "smoke" began to fill Test Tube 2 and eventually began to pass through the small piece of glass tubing.

   When a lighted match was held to the tubing from Test Tube 2, the emission burst into flame and burned continously until nearly the end of the experiment.

   A brownish-yellow liquid formed on the sides and bottom of Test Tube 2.

   A dark brown-black material formed in Test Tube 1. It appeared to be thick and sticky. When cooled, it was very hard and stuck to the glass walls.

   Bits of charred wood were able to streak paper, when cooled.

CONCLUSIONS OF EXPERIMENT 5

DISTILLATION OF WOOD RESULTS IN:	CONFIRMED	REJECTED	UNDECIDED
CHARCOAL	✓		
TAR	✓		
WATER			✓
ALCOHOL			✓
METHANE GAS	✓		

   CONCLUSION I can only partially confirm the distillation of wood as producing tar, methane gas, and charcoal. Although a liquid was observed at the bottom of Test Tube 2, I was unable to confirm the existence of either water or alcohol.
3. Distillation is the breaking down of a solid into various parts by the use of heat. *(Note: This experiment really demonstrates fractional distillation, not ordinary distillation, where a vapor is created and cooled.)*
4. *(Note: This question will apply only to those students whose teacher did not choose to demonstrate the experiment or to those whose teacher demonstrated the bending of glass tubing.)*
5. Charcoal and tar were produced.

6. Possibly water and alcohol were at the bottom of Test Tube 2, but I was unable to confirm this without further experimentation.
7. Smoke and methane gas came out of the tubing from Test Tube 2.
8. Typical Conclusion Chart:

HOW I REACHED MY CONCLUSION FOR EXPERIMENT 5			
DISTILLATION OF WOOD RESULTS IN:	CONFIRMED OR REJECTED	OBSERVATION	ADDITIONAL INFORMATION
CHARCOAL	confirmed	✓	✓
TAR	confirmed	✓	✓
WATER	rejected	✓	✓
ALCOHOL	rejected	✓	✓
METHANE GAS	confirmed		✓

Student Book pages 38-39

The preview of Experiment 6 on Student Book page 38 provides students with practice in calculating with joules. It also leads them to the conclusion that 420 J of energy are required to raise the temperature of 100 mL of water by 1°C. This information will be essential to calculation of the amount of heat energy given off by each nut (Student Book page 41, question 8 *b.*).

Student Book pages 39-41

Experiment 6 (Setup—15 min; Duration—20 min). Experiment 6 would be purer were it possible for students to capture the gases given off by the burning biomass. The apparatus required for this, however, is complicated and would itself act as a diversion from the purpose of the experiment. During the experiment, you might also like to point out to students that the oil in the nuts will sputter and drip when the nuts are burned, and that they should not be startled when this occurs.

Experiment 6, if done carefully, should give students a good idea of some of the basic units used in measuring energy: joules, degrees Celsius, millilitres, and grams. Formally speaking, the unit for specific heat capacity is the joule per kilogram kelvin (J/kg·K). The specific heat capacity of water is 4186.8 J/kg·K. To the nearest hundred joules, this is 4200 J/kg·K.

Since the students are not familiar with the kelvin, and since one kelvin = 1°C, we change this to 4200 J/kg·°C.

Since the mass of the nuts in this experiment is in grams, we change this to 4.2 J/g·°C.

Since 1 mL of water has a mass of 1 g, we change this to 4.2 J/mL·°C.

Since the experiment uses 200 mL of water, we change this to 420 J/100 mL·°C.

Student Book page 41

Answers

1. *(See Student Book page 14.)*
2. **HYPOTHESIS** *(See Student Book page 39.)*
   MATERIALS *(See Student Book page 39.)*
   PROCEDURE *(See Student Book page 39.)*
   OBSERVATION

OBSERVATIONS FOR EXPERIMENT 6	PEANUT	HALF-WALNUT	CASHEW
MASS OF NUT BEFORE BURNING	0.6 g	2.5 g	1.2 g
MASS OF NUT AFTER BURNING	0.1 g	0.3 g	0.4 g
TEMPERATURE OF WATER AT THE START	23°C	19.5°C	19°C
TEMPERATURE OF WATER AT THE END	40.5°C	52.5°C	43°C

   CONCLUSION I confirm that energy is stored in biomass since the mass of each nut was greatly reduced and a great deal of heat energy was produced by the burning of each nut.
3. Biomass is the plant material we eat, digest, and burn.
4. I used a graduated cylinder to measure 100 mL of water.
   a. A graduated cylinder could be used.
   b. A measuring cup could be used but would not be as accurate as a graduated cylinder.
   c. A set of scales could be used (mass of can and 100 g of water).
   d. A 100-mL can could be used, but reading a label would not be as accurate a way since the label statement refers only to the amount of contents not the actual size of the container.
5. *a.* 0.5 g of the peanut was converted to heat energy.

$$\begin{array}{r} 0.6\text{ g} \\ -\ 0.1\text{ g} \\ \hline 0.5\text{ g} \end{array}$$

   b. 2.2 g of the walnut half was coverted to heat energy.

$$\begin{array}{r} 2.5\text{ g} \\ -\ 0.3\text{ g} \\ \hline 2.2\text{ g} \end{array}$$

   c. 0.8 g of the cashew was converted to heat energy.

$$\begin{array}{r} 1.2\text{ g} \\ -\ 0.4\text{ g} \\ \hline 0.8\text{ g} \end{array}$$

6. This is a true statement.
7. *a.*

$$\begin{array}{r} 40.5^\circ \\ -\ 23.0^\circ \\ \hline 17.5^\circ \end{array}$$

b. 52.5°
$-\ 19.5^\circ$
33.0°

c. 43.0°
$-\ 19.0^\circ$
24.0°

8. *a.* 420 J of energy are required to raise 1 mL of water 1°C.

b. Peanut: $17.5^\circ \times 420\ J = 7350\ J$
7350 J were produced by the biomass of the peanut.

Walnut half: $33^\circ \times 420\ J = 13\ 860\ J$
13 860 J were produced by the biomass of the walnut half.

Cashew: $24^\circ \times 420\ J = 10\ 080\ J$
10 080 J were produced by the biomass of the cashew.

EXTENSIONS

Student Book page 37 asks students to design experiments to test any of the substances about which they are unsure. The list of characteristics on this page should provide points of departure for such experiments.

After completing question 8 *b*. on Student book page 41, some students may want to find the amount of energy given off per gram by each nut (the answers in 8 *b*. divided by the answers in question 5). This is the best test of which type of nut has more stored energy.

Chapter 7

Using Biomass Energy

OBJECTIVES

Knowledge

- **state the fuels that can be obtained from biomass**
- **recognize how fuels can be obtained from biomass**
- **explain how biomass from wastes can be used**
- **recognize how biomass is grown for fuel**
- **describe some of the uses of biomass fuels**
- **investigate the consequences of growing biomass for fuel**

Process Skills

- **apply discovered knowledge**

Vocabulary

biogas, bacterium, carbon monoxide, ethanol, ethyl alcohol, fuel, gasohol, hydrogen sulfide, methane, methanol, methyl alcohol, microbe, nitrogen, sludge, slurry, terajoule

Materials

Exercise Sheet 3

TEACHER BACKGROUND

Biogas is made by anerobic bacterial decomposition of biomass. Its main ingredient is methane. Methanol can be made by treating biogas to balance the carbon dioxide, hydrogen, and carbon monoxide, by adding a catalyst, increasing the temperature to three or four hundred degrees Celsius, and putting the biogas under a pressure of 30 000 kPa. It can also be made by the destructive distillation of wood. The vapors produced are condensed and fractionally distilled to produce a lower grade of methanol.

The explanations given in the Student Book are, of course, rather simple. Although ethanol is an extremely important biomass fuel, almost no explanation of how it is made occurs in the Student Book. The interaction of yeast and sugar that makes ethyl alcohol is relatively easy to explain. However, the danger exists that upon learning that ethanol is chemically the same as the intoxicating ingredient in alcoholic beverages, a student may undertake to make and drink it. There are two dangers. First, unless ethanol is precisely made and double distilled, impurities may exist in the final product. These can be poisonous. Second, the alcohol produced is extremely strong, so that even a small amount can cause severe alcohol poisoning, a coma, or even death. It is not only for moral reasons that governments undertake to supervise and regulate the control of ethanol production.

In Canada, those who would produce ethanol must post a $200 000 bond. This has severely hampered citizens who seek to make ethanol for fuel. In many countries, ethanol is denatured (with methanol, a violent poison) at the point of manufacture. In this way, producers escape onerous taxes and consumers know without a doubt that they are not buying a beverage.

CORE

Student Book pages 42-46

Having done Experiment 6 in Chapter 6, students know that biomass can be burned to produce heat energy. Student Book page 42 gives a practical example of this: the burning of wood to heat homes. Although this point is not explained in the Student Book, many people feel that the high-quality woods that make good fuel could better be used for building materials, for furniture, or indeed be left alone. This feeling may even extend to the removal of slash left after logging operations. Many small animals make their homes in slash. If both forest and slash are levelled, what will happen to animal life and to the soil's capacity to support new plant life?

By contrast, the prospect of deriving fuel from the waste of the pulp and paper industry, from cities, and from farms seems pleasing. Student Book pages 42 to 46 discuss this in some detail. These pages cover the production of biogas, methane, methanol, and ethanol.

Exercise Sheet 3

The questions included in Exercise Sheet 3 may assist students in reviewing what they have learned in this chapter, before any extension activities are assigned.

EXTENSIONS

Students should be encouraged to find articles on renewable sources of energy newspapers and magazines. These could be placed in a binder called Renewable Sources of Energy in the News. Such a binder could be a resource file for short essays or reports to the class. It might also serve as a style guide for students who would like to write mock magazine or newspaper articles.

Students may realize that, in any comparison of energy sources, the amount of work that the energy can do depends upon the efficiency of the conversion. Students might be interested in comparing rates of efficiency of renewable and nonrenewable sources of energy such as heating with wood versus heating with oil, solar heating versus heating with gas, and so on.

Social Awareness Should we burn trees for fuel? Should agricultural land be used to grow fuel crops? To discuss these questions, it might be useful to divide the class into four groups. Two groups could investigate the positive sides of the questions, and two groups the negative. For example, one group could investigate the fuel crisis in England in the 1700s that destroyed England's great forests. Another group could investigate the new, fast-growing hybrid poplars and how they can provide inexpensive fuel. Another group could investigate the effect of growing a sugar-cane fuel crop on small land-holdings in Brazil.

Chapter 8

Wind Energy

OBJECTIVES

Knowledge

- **recall that the earth turns from west to east**
- **recognize that warm air rises and has low pressure**
- **recognize that cool air falls and has high pressure**
- **recognize that high-pressure air moves toward low-pressure air**
- **show that uneven heating of the earth's surface by the sun causes wind**

Process Skills

- **do a thought experiment**
- **make drawings from written instructions**

Vocabulary
fantasy, mass, pascal, pressure, volume

Materials
Student Materials—see Student Book page 48

TEACHER BACKGROUND
Thought experiments have three indispensable elements: the willingness to make visual representations; the willingness to do calculations; and, the willingness to go out and do research. Thought experiments are common in certain branches of science. Einstein's work on the photoelectric effect (for which he won the Nobel Prize) depended on thought experiments, as did the bulk of his work on the general theory of relativity. Einstein's thought experiments were filled with drawings and calculations. Crick and Watson worked with large, three-dimensional models in a series of thought experiments that resulted in the discovery (that won them the Nobel Prize) of the molecular structure of DNA.

CORE

Student Book pages 47-51

Experiment 7 (Timing will vary for individual students.) Experiment 7 is a thought experiment. In it, students are spared the need for doing research in the interest of leading them smoothly through their first thought experiment. However, they should understand clearly that this is not a reading exercise. It is an experiment. If they do not make all the drawings and do the calculations for themselves, they will be lost long before the conclusion. Equally important, they will not have a good background for Experiments 10, 11, and 12. Those they must do on their own. You may find that with the thought experiments, you will want to monitor the students closely, to be sure that they feel they do understand each stage and that they have sufficient background to proceed confidently.

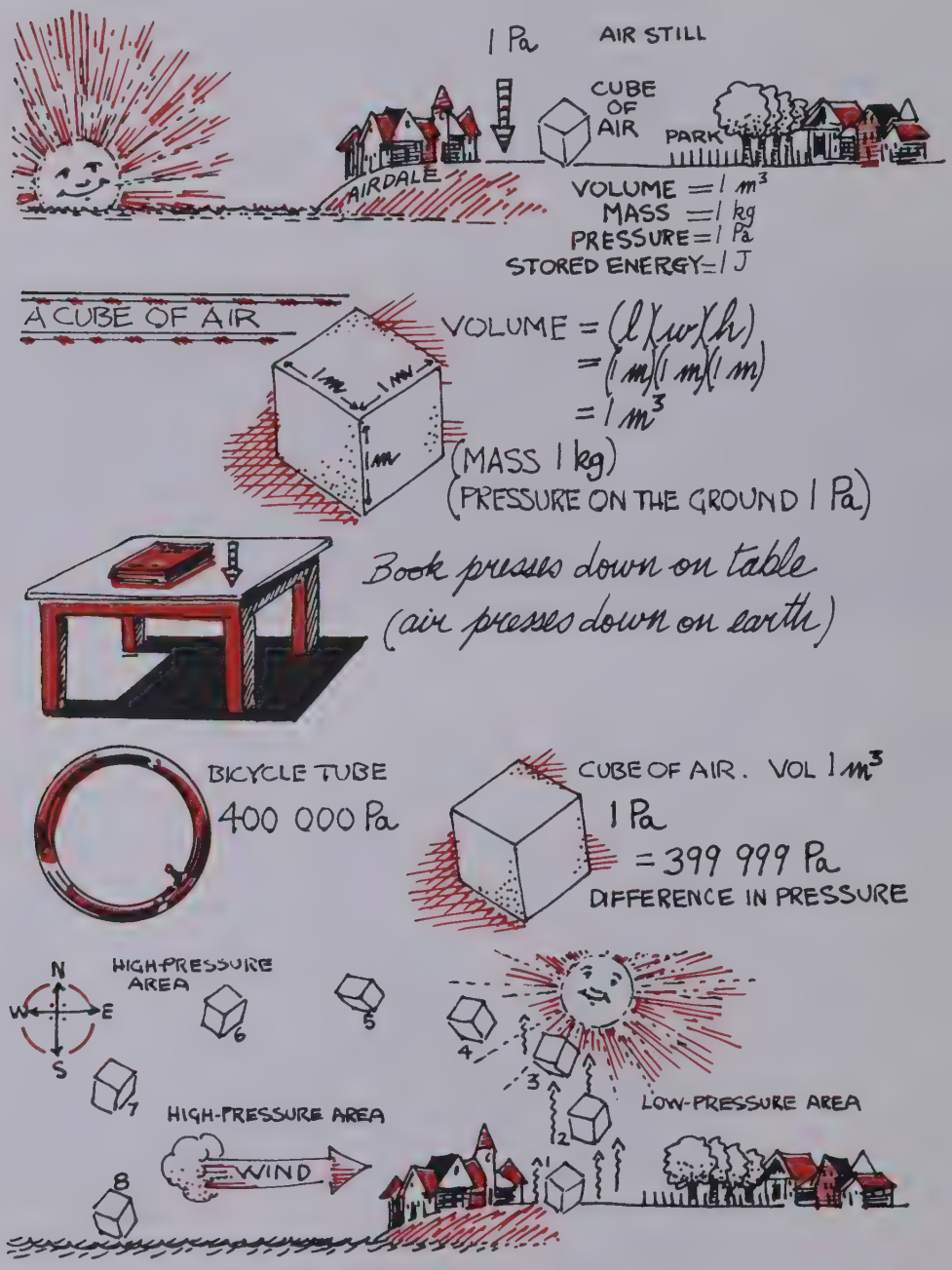
On Student Book page 48, it is said that the cube puts a pressure of 1 Pa on the ground. This is a necessary simplification. It results from averaging 100 000 m^3 of air that together put a pressure on the ground of 100 kPa at sea level. 100 kPa = 100 000 Pa. Averaging over 100 000 m^3, this is 1 Pa/m^3.

Student Book page 51

Answers

1. *(See Student Book page 14.)*
2. *(See Student Book pages 48-50.)*
   No actual materials—only drawing materials—were used. Observations are mental (diagrammatic) images. Logic is involved, more noticeably.

3. When it was impossible to set up a practical experiment in a laboratory, I would use a thought experiment.
4. **PURPOSE** *(See Student Book page 48.)*
   MATERIALS *(See Student Book page 48.)*
   PROCEDURE AND OBSERVATION



CONCLUSION The wind blows from an area of high pressure to one of low pressure. These unevenly heated areas are a result of the solar energy on the surface of the earth.

5. Fantasy is the result of mental images.
6. Albert Einstein used thought experiments.
7. The cube of air, 1 m × 1 m × 1 m, had a volume of 1 m^3.
   The block would have a volume of 2 m^3.
8. The mass of the cube was 1 kg.
   The mass of a block with dimensions of 1 m by 2 m would be 2 kg.
9. The cube puts 1 Pa of pressure on the ground.
   Two cubes sitting, one on top of the other, must exert 2 Pa of pressure on the ground.
10. The 100 000 cubes would exert 100 000 Pa (or 100 kPa) of pressure on the ground.
11. The pressure inside the bicycle tire was 400 000 Pa.
12. 1 J of energy was stored in the cube of air.
13. 400 000 J of energy would be stored in the bicycle tire.
14. 1 J of energy is about as much as energy as that contained in lifting a flashlight battery 1 m.
15. *a.* The person is looking to the north.
    b. The person is looking to the south.
16. Since the air rises as it is heated, and since the air cools as it rises, and since the cool air produces a high-pressure area, and since the wind blows from the west, the earth must therefore have turned from west to east.
17. The sun's solar (heat) energy warms the air.
18. Hot air rises.
19. Hot air has low pressure.
20. As air rises, it cools.
21. Cold air has high pressure.
22. Cold air falls.
23. Wind results from the uneven heating of the air (atmosphere) which produces pockets of high and low pressure. The high-pressure air rushes toward the low pressure and thus creates a "wind" or movement of air.

EXTENSION

Some students might want to investigate thought experiments further by, for example, recreating some of Crick's and Watson's three-dimensional models. Others could do research to find other important discoveries that began as thought experiments.

Chapter 9

Demonstrating Wind Energy

OBJECTIVES

Knowledge

- **become familiar with some of the components of a horizontal-axis windmill**
- **demonstrate that the angles of the blades of a windmill affect the speed at which the vanes of the windmill revolve**
- **recognize that wind has kinetic energy**
- **recognize some of the relationships among kinetic energy, mechanical energy, and potential energy**
- **find out how much energy (in joules) a model windmill can generate**
- **demonstrate that it takes one joule to lift one hundred grams one metre**
- **recognize that power is energy divided by time**
- **recognize that power (in watts) is energy (in joules) divided by time (in seconds)**
- **find out how much power (in watts) a model windmill can generate**
- **demonstrate that a windmill can be used to store energy**

Process Skills

- **control variables in an experiment**
- **formulate plans**
- **build a model**
- **use a protractor to measure the angle of blades**
- **count and record the number of revolutions a blade makes in one minute**
- **make an observation chart**
- **make a line graph from a chart**
- **use characteristics of substances to identify them**
- **write up an experiment with a five-part conclusion**
- **equalize the height above base level of two objects**

Vocabulary
average, blade, kinetic energy, mechanical energy, potential energy, power, revolutions per second, splint, store, tilt, watt, wind energy

Materials
Student Materials—see Student Book pages 52, 54

CORE

Student Book pages 52-53

Experiment 8 (Set-up—45 min to make windmill; Duration—45 min). Much of the effort in Experiment 8 goes into making the model windmill. It would be a good idea to check each windmill to see that each functions smoothly. Of particular importance is the masking tape, which slows the speed so that the revolutions of the blade can be counted—there can be too little or too much tape in one place. The best plan is to give out the same amount of tape for each windmill and to check to see that it is applied smoothly. *(Note: This windmill will be used in later experiments.)*

In this experiment, the students should think through the question of controlling the variables on their own. The best conclusion for them to reach, ideally without too much guidance, is that the fan should tilt neither forward nor backward and that it should be at the same height as the windmill. Also, some students may not fully appreciate the importance of the instruction to place the windmill close enough to the fan that it turns but far enough away that the turns can be counted easily.

Adjusting the angle of the windmill's blades is a painstaking business, but the accuracy of the results depends upon it. Number of blades also affects results.

When observing the windmill in action, students should pick one blade and observe the tip of it. If this proves difficult, there are two remedies: move the windmill farther from the fan, or paint the tip a bright color. Observing the tip is sound because general discussions of windmills often use the tip-speed ratio $(\frac{\text{speed of tip}}{\text{windspeed}})$ rather than the number of revolutions per minute of the shaft.

Student Book page 53

Answers

1. *(See Student Book page 14.)*
2. *(See Student Book pages 48-50.)*
3. *(Answers will vary.)*
4. *(Note: The following typical student response illustrates a situation in which a student was unable to locate a fan with sufficient strength to lift a* 100-g *mass* 1 m. *The student has substituted a hair dryer for the fan. In addition, other substitutions of material were made: a* 10-g *mass for the* 100-g *mass, an* 8-cm *length of hard plastic tubing instead of glass tube, and reduced proportions of* 1 cm *by* 4 cm *for the cardboard blades. Such substitutions are permissible, if the principle of the experiment remains the same. In this instance, the student's fan is able to lift a* 10-g *mass* 1 m *and the results are consequently one tenth of the experiment as originally outlined. This student's version is followed through the related Experiment 9).*

   HYPOTHESIS *(See Student Book page 52.)*

   MATERIALS *(See Student Book page 52, with substitutions as noted above.)*

   PROCEDURE Glue one wooden splint into a 3-cm rod. Repeat until all 8 rods have wooden splints attached to them. Allow glue to dry.

   Tape cardboard blades (made from file folders) to wooden splints using clear cello tape.

   Color one blade a bright color (red).

   Insert rods into the spool.

   Insert 13-cm rod into the hub of the spool.

   Place the clear plastic tubing over the 13-cm rod and add a tight-fitting washer to keep it in place. However, give the tubing a space to move of perhaps 4 mm or else it will impede the windmill's turning.

   Wrap masking tape around the plastic tubing so that the windmill can be clamped in a horizontal position on the utility stand.

   Clamp the hair dryer to another utility stand and adjust both the fan and the windmill so that the force of the air will strike the face of the windmill at a 180° angle (face-on). Nozzle of hair dryer should be about 30 cm from windmill.

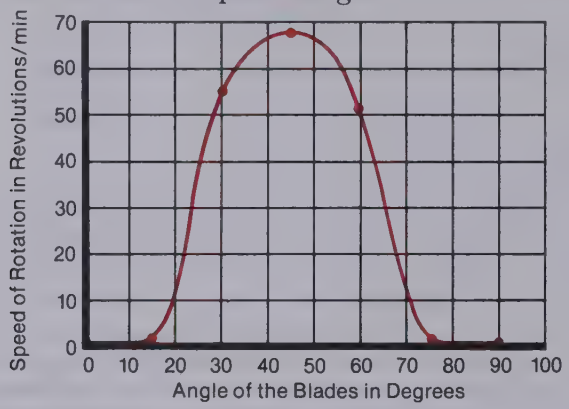
   Adjust the blades with a protractor to read 45° to the 13-cm rod.

   Repeat the last step for angles of 60°, 75°, 90°, 30°, 15°, and 0°.

   OBSERVATION

DEGREE OF BLADE ANGLE	NUMBER OF REVOLUTIONS PER MINUTE
90°	0
75°	0
60°	52
45°	68
30°	56
15°	0
0°	0

CONCLUSION I confirm the hypothesis that the angle of the blades of a windmill affects the speed at which the vanes revolve. I found that the maximum number of revolutions per minute was at an angle of 45°. After 60° and 30°, the number of revolutions per minute of the blades dropped off sharply to 0. The optimum blade angle would therefore appear to be between 30° and 60° with the peak being at 45°.



Student Book pages 54-55

Experiment 9 (Set-up—15 min; Duration—45 min). Experiment 9 uses the windmill made in Experiment 8. (The same windmill may be required for Experiment 10.) Here it is used to lift a 100-g mass a distance of 1 m. Doing this requires 1 J of energy. The material from the conclusion on Student Book page 54 to the end of the review on Student Book page 55 is crucial to an understanding of wind energy and how it is measured. This material should be understood by every student, even at the expense of repeating material that some students have learned quickly.

Question 5 on Student Book page 55 is designed to evaluate students' retention of what was learned in Experiment 8. The question really asks: Did you set the blades of your windmill at an angle that you knew would give the fastest tip speed, or did you unthinkingly use whatever angle the blades happened to have?

The second observation, that when the fan is turned off the 100-g mass falls and the blades turn in the opposite direction, confirms the hypothesis. The energy that turns the blades while the mass falls is stored energy. When the mass stops falling, the stored energy is used up.

Student Book page 55

Answers

1. *(See Student Book page 14.)*
2. *(Note: The following typical student response is a continuation of that presented for Experiment 8. The electric fan has been replaced by an electric hair dryer, the 100-g mass by a 10-g mass, and the student has used 1 m of fishing line instead of string, to reduce friction.)*
   HYPOTHESIS *(See Student Book page 54.)*
   MATERIALS *(See Student Book page 54, with substitutions as noted above.)*
   PROCEDURE Set up windmill so that the end of the 13-cm rod is over the edge of the table. Adjust hair dryer nozzle so that it is in a direct line 30 cm from the face of the windmill.

   Tie one end of the fishing line to the rear shaft of the windmill and wrap it with masking tape, to extend it slightly.

   Tie the other end of the fishing line to a 10-g mass so that when suspended it is exactly 1 m from the shaft.

Turn on the hair dryer and record observation.

Turn off the hair dryer and record observation.

Repeat these last two steps four more times.

OBSERVATION

TRIAL	NUMBER OF SECONDS IN WHICH 10-g MASS RAISED
1	33 s
2	34 s
3	32 s
4	32 s
5	31 s

When the hair dryer was turned off, the 10-g mass fell back to its original position, causing the blades of the windmill to turn in the opposite direction.

CONCLUSION I confirm the hypothesis since the 10-g mass was raised and before falling had potential energy to do work (to turn the blades in the opposite direction).

3. The moving air has kinetic energy.

   The blades have mechanical energy (which is a form of kinetic energy).

   Potential energy is created (eventually, when the mass is at the top).

   Potential energy is converted into kinetic energy when the mass begins to fall.

4. 33 s
   34 s
   32 s
   32 s
   31 s
   162 s

   $5\overline{)162\text{ s}} = 32.4\text{ s}$

   The average time for the windmill to raise a 10-g mass was 32.4 s.

5. *(Answers will vary.)*

6. *a.* The windmill generated 32.4 rev/s.
   b. My windmill generated 0.1 J of energy. *(Note: If the experiment is followed as outlined in the Student Book, the answer would be 1 J. This answer reflects the substitution of the hair dryer for the electric fan and the use of a 10-g mass instead of a 100-g mass.)*

7. $P = \frac{J}{s}$

   $P = \frac{0.1\text{ J}}{32.4\text{ s}}$

   $P = 0.004\text{ W}$

   The windmill had a power of 0.004 W.

EXTENSIONS

Following Experiment 8, students might be asked to find the optimum size of blades for their particular model and source of wind.

In Experiment 9, the students have learned that the energy of wind can be used to lift mass. Some students might be interested in researching the many other ways that windmills can be used to do work for us.

Some students might be interested in investigating another sort of turbine—the water wheel. Students could research the differences and similarities between water wheels and windmills.

Chapter 10

Using Wind Energy

OBJECTIVES

Knowledge

- **list four types of horizontal-axis windmills**
- **list three types of vertical-axis windmills**
- **state the parts of a windmill that make electricity**
- **state three types of energy storage used by windmills**
- **recognize that, during the day, warm air rises and blows from land out over water and cool air blows across water and onto land**
- **recognize that, at night, warm air blows from land over water and cool air falls onto land**
- **show that, during the day, mountain slopes, because of their angle to the sun's rays, heat up faster than valleys so that cool air flows up mountain slopes from valleys**
- **show that, at night, valleys cool more slowly than mountain slopes so that cool air flows down mountains into valleys**
- **become familiar with an anemometer**
- **become familiar with the Beaufort scale of winds**
- **rate windspeeds as suitable or unsuitable for windmills**
- **investigate the environmental consequences of using wind energy**

Process Skills

- **apply ideas gained from doing experiments in order to understand written materials**
- **design an experiment**
- **consolidate insights gained from previous experiments**
- **do a thought experiment independently**
- **make and label diagrams**
- **read instructions and make an anemometer**
- **read an anemometer**
- **read a wind scale**
- **compare a wind scale with a wind-speed rating chart**

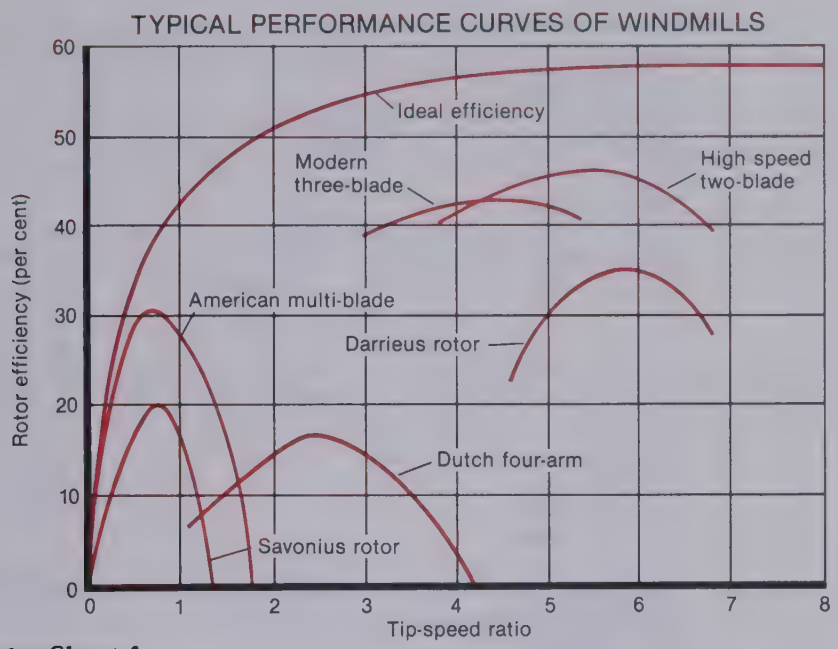
Vocabulary
anemometer, alternating, alternator, average, breeze, calm, current, Darrieus rotor, Darrieus-Savonius rotor, direct current, four-arm windmill, gale, generate, generator, gust, hurricane, horizontal axis, inverter, multi-blade windmill, propeller, Savonius rotor, storm, vertical axis, voltage regulator, wind vane

Materials
Student Materials—see Student Book page 59
Exercise Sheets 4, 5

CORE

Student Book pages 56-57

The typology of windmills is based primarily on the orientation of the axis. Horizontal-axis windmills have the advantage of starting easily and not stalling readily. Vertical-axis windmills do not have these problems as a small Savonius rotor is used to get them started and keep them going in times of little wind. (Two advantages of vertical-axis windmills are pointed out on Student Book page 57.) Efficiencies of various windmills are given in the following graph. Rotor efficiency is given as a per cent of available wind power extracted by the rotor.



Exercise Sheet 4

Students may use these questions to review what they have learned before attempting Experiment 10.

Experiment 10 (Timing will vary for individual students.) Experiment 10 will most likely appeal to eager students, some of whom may spend a lot of time on it. The problem is to design an experiment or experiments, not necessarily to carry out what one has designed. Only the best students will realize that all these factors act in concert and that a good design achieves a balance among them.

Student Book pages 58-59

The difficulty of storing energy from wind is the reason why wind energy is not used more widely. Several alternatives to storage are proposed here for discussion by the students.

The experiments in this section are thought experiments. Students must remember to write them up according to the steps in Experiment 7 (Chapter 8). They must be prepared to draw diagrams, to do calculations, and to do research.

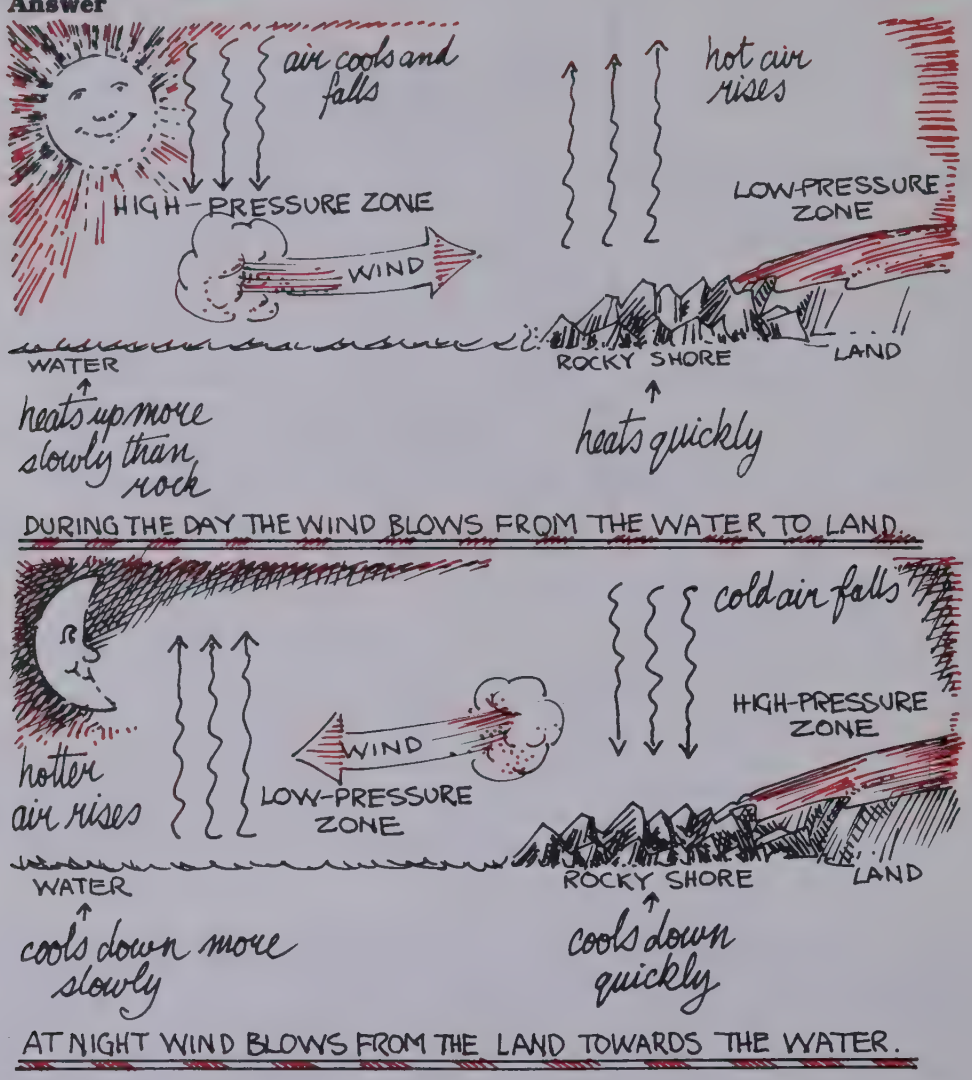
Students should again expect to sit and think, to go to the library, to ask questions in class, to draw diagrams and label them, to get data and insights from previous experiments and reading activities, to look back in their notebooks, and in short, to spend as much time on these experiments as they would on any other experiment.

Re-emphasize that it is all right to have false starts, to discard ideas and approaches, to ask questions, to get information and ideas wherever they can. Remind students that they are experiencing another way of doing science, a way that is as valid as the concrete activities they have done so far.

Experiment 11 (Timing will vary for individual students.) Experiment 11 makes use of insights gained in Experiments 7 (Chapter 8) and 3 (Chapter 3). The former gives insight into why wind blows, how to draw diagrams, and how to set up the experiment. The latter gives data above the relative rates of heat gain and heat loss of rock and water. These data can be used in calculations.

Student Book page 58

Answer



Experiment 12 (Timing will vary for individual students.) Experiment 12 also depends upon one's having done Experiment 7 (Chapter 8), for the same reasons as those given for Experiment 11. Also, this experiment uses insights from Experiment 1 (Chapter 3) and the section on greenhouses (Chapter 4).

Student Book page 59

Answers

(Answers will vary.)

Student Book pages 59-61

The simple anemometer described on Student Book page 59 should give students a fairly good idea of wind velocity when used with the charts on Student Book pages 60 and 61. For materials, students could also use a large clear plastic protractor with a hole at the 90° angle and base line—fishing line may be tied in this way, rather than being glued.

The activity on Student Book page 61 takes the students out of the classroom. It is excellent for a full-scale field trip, but any location out of doors is adequate.

Since taking readings over a number of months may not be practical, the notion of averaging wind speeds may be explored by taking readings every five minutes for an hour.

Back in the classroom the data gathered may be correlated with the Beaufort scale of winds on Student Book page 60. Ratings may be assigned to sites using the scale on Student Book page 61.

Students may also use weekends to gather data from other sites of their choice. Maps may be drawn up of possible local windmill sites. The considerations at the bottom of Student Book page 61 would come into play at this stage.

Exercise Sheet 5

Some students might be interested in why airplanes fly. Exercise Sheet 5 has been included because it reinforces the principles of air pressure that are so essential to an understanding of wind. Some students may be able to understand that the propellers of airplanes change pitch with the speed of the vehicle, just as some windmill blades change pitch with the speed of the wind.

Exercise Sheet 6

Exercise Sheet 6 is a map of Canada. Some locations are given, along with their average monthly windspeeds. Students are to place a Beaufort number beside each location and a rating from the scale on Student Book page 61.

EXTENSIONS

The map on Exercise Sheet 6 may be extended by using information from reference books, radio or television stations, airports, pilots' clubs, sailing clubs, gliding clubs, hang-gliding clubs, weather bureaus, or the Department of Transport and Communications in Ottawa. Students may want to divide up and seek information in different places. Information gathered by the entire class could be placed on a large wall-map of wind-speed information across Canada.

Social Awareness What would be the advantages of a wind-powered world? To answer this question, have the students form groups and brainstorm among themselves about a totally wind-powered world. In order to present their ideas to the class, each group could produce a short diary—"A Day in the Life of. . ."—describing a day in the life of a person living in a totally wind-powered world. Student-produced illustrations might help to show what this kind of a world could be like. Students should explain how their hypothetical wind-powered world is better than the world in which they actually live (less pollution, less noise, less dependence on fossil fuels). Publications such as *Harrowsmith* often include articles on the ways in which real people live a wind-powered life. Students could find such articles to prove that the notion is not as fantastic as it seems.

Social Awareness Would you like a wind-generator park built beside your town? This question could be debated using a town-meeting format. Each student could be assigned a role (shopkeeper, teacher, coal miner, construction worker, energy expert, homeowner, and so on) and be prepared to present his or her role reaction to the building of a wind-generator park. For example, homeowners close to the park would probably react negatively because the park could be noisy and unattractive. Homeowners on the other side of town might find the park to be a good idea because their electricity would be produced in a cheaper, less polluting way. Coal miners would be against the park because they would lose their jobs if the town's coal-fired thermal-generating station were to be shut down.

When each student has presented his or her role's position, the class—as a town council—should vote on the questions.

Chapter 11

The Future of Renewable Energy Sources

OBJECTIVES

Knowledge

- **recall the information presented in this unit**

Process Skills

- **apply discovered knowledge**

CORE

Student Book pages 62-63

The purpose of this culminating activity is to have students discover for themselves why renewables are not used as widely as this unit may seem to suggest they might be. In their investigations they may find examples of areas where some renewables *can* be used economically and practically. But they will also learn that, in some cases, the use of certain renewables is not practical now and may never be practical.

To aid students, you might like to provide them with lists of typical costs (for home heating with oil, gas, and electricity, for example). They could then find comparable costs for using renewables. You could also supply them with a list of places in your area where renewables are already being used. Some students could interview people at these locations to find out how well renewables are working and discuss questions such as the costs of installation, the effect on lifestyle, and so on.

The most important concept that students should learn from this activity is that, although renewables are and can be a useful source of energy, they are not a panacea. We might always have to find other ways to supplement the energy we get from renewables.

EXTENSION

Social Awareness Could your community successfully switch to renewable energy resources? You might like to divide the class into five groups for a discussion of this question. Each group should represent a different point of view and develop a plan that supports that point of view. One group, for example, could support a completely solar-based system. Another group could support a combination of wind and water power; a third group could propose a methane-using system, and a fourth group could propose using ethanol as a fuel. A fifth group, the judges—composed of one member from each of the four groups and a chairperson—should examine each of the plans to decide which one (or combination of plans) would be the most successful. The judges would have to consider the following: the availability of the natural resources proposed; whether or not these resources can produce enough energy to replace oil and natural gas; whether or not technology has advanced far enough for the plan to be carried out; how much the changes will cost; and, what effect the plan will have on everyone's lifestyle.

As each plan is proposed, the judge from that group must defend it to the other judges and to the class as a whole. When the final decision has been reached, the class should write a brief description of the most successful plan. Preferably, this plan will be a combination of all the plans, to make the best use of all the resources available.

Renewable Sources of Energy
Exercise Sheet 1

For use with Chapter 2

1. The sun is how many times as large as the earth?
2. The matter at the core of the sun is
   a. gas *b.* liquid *c.* solid *d.* plasma.
3. What is the name of the reaction that turns hydrogen into helium?
4. Why do atoms collide in the core of the sun?
5. How many tonnes of hydrogen does the sun change into solar energy each second?
6. How many megajoules of solar energy reach the earth each second?
7. How much energy is one joule?
8. How much energy is one megajoule?
9. What happens to the solar energy that reaches the earth?
10. What is the surface area of two quarters?
11. Imagine two quarters lying on the ground in Edmonton, Alberta for one year. Assume there are no tall buildings or trees around. Assume no one picks the quarters up and that they are not covered over by snow or leaves.
    a. How much solar energy strikes the quarters in one year?
    b. During what month do they get the most solar energy?
    c. During what month do they get the least?
    d. What are the best four months for solar energy?
    e. What are the worst four months for solar energy?
    f. Some months are better than the four worst months put together. Name them.
12. Is the amount of solar energy that strikes the earth a lot or a little? Explain your answer.
13. What are the two main problems that have to be solved in order to take advantage of solar energy?
14. Silicon cells are used to change the sun's energy into what form of energy?
15. Name two problems with silicon cells.
16. What does it mean to store energy?
17. Give two examples of storing the sun's energy.
18. What is the most practical use for solar energy today?
19. What device is used to accomplish your answer in number 18?
20. The following topics are for essays. Pick one topic and write a one-page essay. Be brief and to the point. Use diagrams.
    a. What Is the Sun?
    b. How Big Is the Sun?
    c. How Does the Sun Produce Energy?
    d. How Much Energy Does the Sun Produce?
    e. How Much Solar Energy Does the Earth Receive?
    f. How Can We Use Solar Energy?
    g. Examples of the Four States of Matter.

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Renewable Sources of Energy
Exercise Sheet 2

For use with Chapter 4

1. Write a list of things you have learned from doing Experiments 1, 2, and 3.

2. Imagine a greenhouse with a window facing south. The window goes all the way to the ground. For the questions below draw diagrams.

   a. Calculate the angle of the window to the ground for greenhouses at the following latitudes.

	Latitude		Latitude
Windsor, Ont.	42°	Lethbridge, Alta.	50°
Ottawa, Ont.	45°	Calgary, Alta.	51°
Moncton, N.B.	46°	Saskatoon, Sask.	52°
St. John's, Nfld.	47°	Prince Albert, Sask.	53°
Victoria, B.C.	48°	Edmonton, Alta.	54°
Vancouver, B.C.	49°	Prince George, B.C.	54°

   b. Below, you will find the angle of the sun's rays to the ground on the coldest day of the year for twelve locations. Calculate the best angle of a greenhouse window to the ground for each location.

	Angle of Sun's Rays		Angle of Sun's Rays
Halifax, N.S.	29°	Winnipeg, Man.	23°
Fredericton, N.B.	27°	The Pas, Man.	20°
Nappan, N.S.	27°	Grande Prairie, Alta.	18°
Charlottetown, P.E.I.	26°	Churchill, Man.	14°
Thunder Bay, Ont.	25°	Whitehorse, Yukon	12°
Corner Brook, Nfld.	24°	Yellowknife, N.W.T.	11°

3. What happens when the sun's rays enter a greenhouse? Use diagrams in your answer.

4. What does the word *radiate* mean?

5. What does the word *translucent* mean?

6. What is the Greenhouse Effect? Use examples from the experiments you have done.

7. What types of trees would you plant around a house? Where would you plant each type? Why?

8. What are the parts of a solar collector?

9. How can a solar collector help heat a house? Use diagrams in your answer.

10. What is a thermostat?

11. What is a passive heating system?

12. What is an active heating system?

13. What is a photovoltaic collector used for?

14. How does a photovoltaic collector work?

15. A photovoltaic collector turns the sun's energy into what form of energy?

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Renewable Sources of Energy
Exercise Sheet 3

For use with Chapter 7

1. Define the word *fuel*.
2. Imagine a stack of sugar-maple wood 2 m × 6 m × 9 m stored in a dry shed.
   a. How many cubic metres of wood are there?
   b. How much heat energy can that much sugar-maple wood give off?
   c. How long would it heat a typical home?
   d. How much heating oil would it replace?
3. What is slurry?
4. What is biogas? Make a list of the substances that are in it. Underline the ones that are valuable fuels.
5. What is the chemical name for methane? Is methane a solid, liquid, gas, or plasma?
6. How many atoms of hydrogen are in a molecule of methanol? How many atoms of carbon? What else is in methanol? What is the difference between methane and methanol?
7. What is methyl alcohol? What is wood alcohol?
8. Look at the second column of page 43. Copy the table called *Urban Garbage by Per Cent*. One thousand kilograms equals one tonne. Assume that 23 000 000 Canadians live in cities. Add a column for tonnes per day (t /d) and a column for tonnes per year (t /a). The first line of your table should look like this.

URBAN GARBAGE	%	t/d	t/a
glass containers	11%	5060 t	1 846 900

9. Look at the table you made for number 8. How much organic (biomass) garbage is there per day? per year? What could it be used for?
10. What can manure from farms be used for?
11. How many tonnes of plant wastes from farms are there per year? What can they be used for?
12. What is the chemical name for ethanol? What is another name for ethanol?
13. Is ethanol a solid, liquid, gas, or plasma?
14. What is gasohol?
15. How many atoms of carbon does a molecule of ethanol have? How many atoms of oxygen? How many atoms of hydrogen? What is the difference between ethanol and methanol?
16. What is piesel?
17. Look again at your notes for Experiment 6 (Chapter 6). What substance in the peanut do you think holds a lot of the stored energy? How would you test your hypothesis?
18. How does the energy stored in vegetable oils compare to the energy stored in alcohol fuels?
19. What are distress grains? What are cull potatoes? How can they be used?
20. Name a source of diesel fuel other than petroleum and vegetable oils.
21. What are some advantages to using biomass to make fuel?
22. What are some disadvantages to using biomass to make fuel?

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Renewable Sources of Energy
Exercise Sheet 4

For use with Chapter 10

1. What is a horizontal-axis windmill?
2. What is a vertical-axis windmill?
3. You made a windmill for Experiment 8 in Chapter 9. Was its axis horizontal or vertical?
4. What happens to a horizontal-axis windmill when the wind changes direction?
5. What happens to a vertical-axis windmill when the wind changes direction?
6. How many blades does a horizontal-axis windmill have?
7. Name four types of horizontal-axis windmills.
8. Name three types of vertical-axis windmills.
9. What are the parts of a windmill that make electricity?
10. What is the difference between an alternator and a generator?
11. A windmill that has a generator needs one part that a windmill that has an alternator does not need. What is it?
12. If a windmill with a generator needs an extra part, why don't all windmills use alternators?
13. Name three types of energy storage that windmills can use.
14. Pick one of the following topics and write a one-page essay on it.
    - Which Is the Best Type of Horizontal-Axis Windmill?
    - Which Is the Best Type of Vertical-Axis Windmill?
    - How Does a Fan Work?
    - How Does a Helicopter Work?
    - Why Does the Wind Blow?
    - How Does a Windmill Capture the Wind's Energy?
    - How Does a Windmill Store Energy?
    - How Is Windmill Energy Measured?

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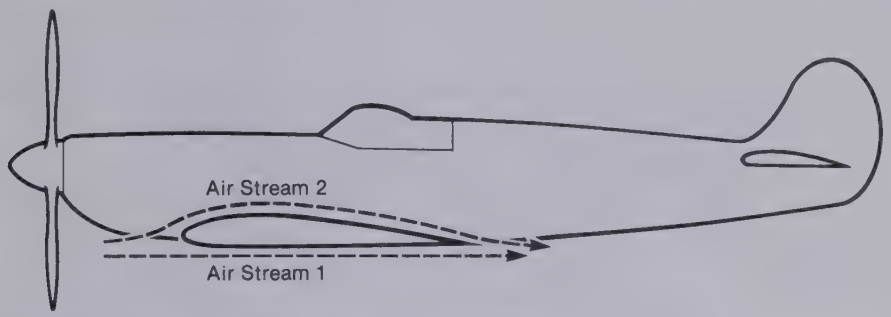
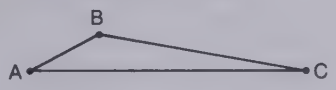
A simple thought experiment will show you that any airplane has more mass than the air around it. Why do airplanes not fall to the ground? First, let us take a look at the wings. Imagine that you are looking at an airplane wing from the side. Notice how the wing is made.



The wing is almost flat on the bottom. It is curved across the top.

Now imagine a stream of air hitting the leading edge of the wing. It breaks into two streams of air. One of these is Air Stream 1 in the drawing above. Air Stream 1 goes straight under the wing. Air Stream 2 goes over the wing and meets Air Stream 1 on the other side of the wing. These two streams of air meet each other on the other side of the wing at the same time. But Air Stream 2 had farther to travel. If Air Stream 2 went farther in the same time, it must have gone faster. You can see this in a drawing.



Someone who goes straight from A to C has taken a shorter path than a second person who goes from A to B and then to C. But if they get to C at the same time, the second person has travelled faster.

In Experiment 7 (Chapter 8), you learned about pressure. Air that has low pressure moves faster than air that has high pressure. Look again at the diagram of the airplane wing. If Air Stream 2 is moving faster, it must have lower pressure than Air Stream 1. The air above the wing is lower in pressure. The air below the wing is higher in pressure. The air below the wing puts more pressure on the wing and pushes it up. The airplane rises.

What makes the air flow in the first place? In Experiments 8 and 9 (Chapter 9) you worked with a fan. The fan has a motor that turns the blades around. The blades make a stream of air that goes forward. An airplane propeller is like a fan that is mounted backward. It makes a stream of air that goes backward toward the tail of the plane. When the propeller pushes the air back, the plane rolls forward on its wheels. As it rolls, its wings slice through the air. The air under the wings has high pressure and lifts the wings. Soon the plane is off the ground.

1. Is the bottom of an airplane wing flat or curved?
2. Is the top of an airplane wing flat or curved?
3. Does the air that moves under an airplane wing have high or low pressure?
4. Does the air that moves over an airplane wing have high or low pressure?
5. What creates the air flow over and under an airplane's wings?
6. Do airplanes have more or less mass than the air around them?
7. Why do airplanes not fall to the ground?

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Renewable Sources of Energy
Exercise Sheet 6

For use with Chapter 10

Each location shown has a monthly wind speed in kilometres per hour. Beside each location, draw a flag. On the flag put the appropriate Beaufort number. Draw another flag beside each location. On that flag put a windmill-site rating: poor, marginal, fair, good, or excellent.

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PROFESSIONAL REFERENCE GUIDE

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Introduction

The SEEDS materials have been designed for use either as an energy unit in a core science/social awareness curriculum or to stand on their own as an energy curriculum. The Teacher's Guides and Teacher's Resource Books of the SEEDS program present strategies and techniques for the *how* of teaching the program's energy literacy concepts and skills. This Professional Reference Guide provides a comprehensive view of the *what* and the *why*. The cross-level content development, the spiral pattern of expanding concepts, the learning/thinking/valuing skills, and the progression and interrelationship of objectives and skills from level to level are summarized in subsequent sections and charts. However, it is important at this point to re-state the original motivation and rationale for the program.

Robert Westbury, Executive Director of the SEEDS Foundation, summarized the history of the Foundation and the development of the Curriculum Project in a brief Preface at the beginning of each Teacher's Guide and Teacher's Resource Book. Two statements bear repeating here: The primary goal of the Foundation—"to encourage the development of an energy-literate society, a society concerned about and committed to the wise use of energy"; and the rationale for the educational modules that comprise the Curriculum Project—"to help young people develop informed views on energy and the environment and act on them."

In the process of preparing the material for publication, Dr. Westbury was intrigued to find that another concerned educator, Rodney F. Allen, had independently compiled the following list of "justifications" for energy education in the booklet, *Energy Education: Goals and Practices*, published by the Phi Delta Kappa Educational Foundation in 1980:

"*Educated Citizenry Justification:* A basic premise of democracy is that citizens with adequate skills and knowledge participate in making the decisions that affect them. Solutions to energy problems require a knowledge of, and participation in, the political process. Traditionally, education has served to equip citizens with the knowledge and skills needed to make such decisions and to take action.

"*Economic Justification:* Energy education is needed so that citizens may make rational choices in their personal lives about public policy questions.

"'*Doing Good*' *Justification:* Energy education offers the opportunity to create a more just and humane society. It can provide the re-educative process that will lead to a more environmentally sound lifestyle and a more equitable distribution of goods and services in the national and world community.

"*Problem-Solving Justification:* Solving widespread energy and environmental problems can be undertaken by a well-educated citizenry. Since energy is so directly related to the conditions that sustain life and give it meaning, educational programs are needed to provide the techniques for solving the energy crisis.

"'*Take Care of Self*' *Justification:* Energy education can teach people how to conserve energy and to make decisions to optimize their personal resources and well-being. Such learning will build personal responsibility and will help to protect personal effects.

"*Educated Person Justification:* Society is beset with technological problems about resource use that require educated and inquiring minds. Energy education should be part of general education now and in the twenty-first century. A sound knowledge of energy concepts and issues should be expected of all educated people

"*Career Education Justification:* Many of today's students will find careers in energy industries (e.g., solar installation, energy audits, and energy-efficient construction) or in industries that depend on crucial energy decisions. Schools have a role in preparing students for these and other careers.

"*Stewardship Justification:* Energy education, like environmental education, offers an opportunity for persons to learn a "common good" ethic, where the well-being of all people (including those yet unborn) is taken seriously in resource use and in the allocation of goods and services. If everything is connected to everything else, we need to learn those relationships and to use them. The welfare of all and responsibility to the posterity of our nation are central themes in this argument.

"*Apocalyptic Justification:* We must learn the wise use of energy resources since there is such a limited supply of nonrenewable energy resources. National survival and the well-being of the world community depend upon effective and equitable use of energy to ward off resource depletion on the one hand and environmental disaster on the other. We need people who can stand at Armageddon and do battle for our survival.

"Whether or not one concurs with all of the justifications offered here for energy education programs in the schools, learning about energy is essential for the social education of all children whose lives will extend well into the twenty-first century. In responding to dwindling energy supplies, our technological advances may be spectacular. Legislation may force us into immediate conservation efforts. Pricing mechanisms may cause lifestyle changes. But in the long run, it is the knowledge, abilities, and personal commitments of the people in a free society that will permit successful responses to the energy crisis."

The Foundation does not claim such all-encompassing justifications for either its own existence or the curriculum materials, but interwoven in its name are the three topics that recur in the descriptions above—Society, Environment, and Energy. The main ideas grouped into these three strands evolved from the preliminary content analysis undertaken by the educators for the preparation of the curriculum materials.

The main ideas provide the broad organizing concepts, drawn from the social sciences, the natural sciences, and the physical sciences, that recur from level to level throughout the program. They are presented within different contexts and with gradually increasing complexity as the students progress. The process of concept-learning is inherent in the specific objectives, stated in terms of learning outcomes expected for the students.

We have used the term "energy literacy" to describe this process designed to lead to the development of informed views on energy and the environment. But the objectives also reflect the behavioral goals of changing one's attitude, of taking action on a personal level and in related social issues, of conserving energy where possible, of wisely *using* rather than *abusing* our natural resources.

Definitions and Concepts

In developing the main concepts from the social, the natural, and the physical sciences, the presentation in the student materials has been written to the level of the average student's understanding. This has, at times, necessitated the simplification of explanations or definitions. For example, the statement "energy is the ability to do work," while satisfying to scientists, is only puzzling for most students. Students can more easily gain an appreciation of the meaning through activities and experiences that broaden their understanding.

For more capable students, more detailed definitions or explanations should not be avoided. But all students should be encouraged to continue testing, exploring, investigating, and discussing observations until they can give a satisfactory explanation in their own words. At that point, the name for a concept or the accepted definition can be provided by the teacher.

For this reason, we have provided some background information for teachers who may not have a full command of the concepts dealt with in the program. These Teacher Background sections are provided to reduce the need for teacher preparation. However, there is no substitute for in-depth teacher preparation and practical investigation since both teachers and students benefit from the processes of investigating, hypothesizing, and testing in order to gain a better understanding of how our world functions. Teachers should be aware that the following topics in particular have been presented in a simplified form in all components of the elementary levels and in increasing detail in the upper levels of the SEEDS program: the definition of energy, the definition of solar energy, the description of energy flow on earth, and the definitions of "renewable" and "nonrenewable" as applied to sources of energy. For teachers who feel that their students can benefit from an earlier technical introduction to these topics, the following essay should prove helpful.

Energy is a quality or state of an object or set of physical circumstances. Energy can be thought of as the source of all activity in the physical world. Physical phenomena represent transformations or exchanges of energy. Thus, the classical definition of energy as "the ability to do work" reflects the difficulty we have in defining it as a concrete, physical entity. We tend to quantify and describe energy in terms of what it can *do* rather than what it *is*.

On earth, our main source of energy is the sun which is a middle-aged star, about four and one-half-billion years old, that has not yet exhausted its hydrogen fuel. Spectral analysis of the sun's light and other astronomical data indicate that about three-quarters of the sun's mass is hydrogen; about 20% or more is helium; and the remainder is composed of traces of elements like carbon, nitrogen, oxygen, magnesium, and silicon.

Using information gained partly by observation and partly by theoretical models, scientists have described the sun as composed of various layers: the *core* where thermonuclear reactions occur; the *convection zone;* the *photosphere* or deepest visible layer; the *reversing layer;* and the *atmosphere*, composed of the *chromosphere* and the *corona*. The atmospheric layers may have temperatures of over 1 000 000°C but the photosphere is only about 6 000°C. From the photosphere inwards, the temperatures, pressures, and density of material increase dramatically. The temperature of the core is about 20 000 000°C. At the temperatures and pressures encountered near the center of the sun, only the most elemental forms of matter can exist—atomic nuclei must be nearly stripped of their electrons. *Plasma* is the term used to describe this "fourth state of matter" which is not solid, liquid, or gas.

The sun is like a gigantic hydrogen bomb generating energy in its core at a prodigious rate. It is believed that two hydrogen nuclei fuse to form one helium nucleus, subsequently releasing

energy in the process. It has been estimated that some 597 000 000 t of hydrogen fuse to form 593 000 000 t of helium every second. Because of the vast quantity of hydrogen present, the sun will continue producing energy at this rate for billions of years. As the hydrogen supply becomes depleted, and the sun's composition becomes less homogeneous, another set of nuclear reactions may cause the sun's luminosity and size to increase so much that the earth will boil away. However, this may occur some four and one-half-billion years hence.

The energy released in the sun's core is transported to the surface by a combination of radiation and convection. *Convection* is the transmission of heat energy by the physical movement of material; *radiation* is the transmission of energy by photons. Radiation dominates in the interior regions and convection in the outer quarter of the sun's radius, terminating just below the photosphere. In the photosphere, radiation takes over completely. The earth's upper atmosphere receives only about one two-billionth of the sun's radiant energy. About 30% of this is reflected back into space. The remaining portion warms our planet, generates the ocean currents, drives the local and global wind and water cycles, and sustains life.

Only about 0.03% of the incident solar radiation is captured and converted into organic matter by green plants through the process of photosynthesis. Much of this material will eventually decay and thus release its stored solar energy. Over the last six hundred million years or so, a very minute fraction of organic matter has been deposited in oxygen-deficient environments and thus has been preserved in the form of fossil fuels—the so-called nonrenewables. Other sun-dependent energy sources, such as wind, water, and biomass, have been classified as the renewables.

The classification scheme for determining whether or not a particular energy source is renewable or nonrenewable depends on how one wishes to interpret the factors considered in the definition, such as the type of source, the amount present, its rate of consumption, and/or rate of formation, as well as the time scale being dealt with. The fossil-fuel stock is being replenished through processes similar to those that created it in the past, yet at about the same rate as in the past. Thus we could argue that the term "nonrenewable" is inappropriate. But, fossil fuels are being consumed at a far greater rate than their present rate of formation. In several centuries, they may not be available for us to use, but several million years from now, they may possibly be available again.

A similar argument can be developed for biomass energy from trees. We can say that trees replace themselves (reproduce) in a relatively short period of time. Thus, they are a renewable energy source. Yet if the rate of consumption outpaces the rate of replacement, this source of energy effectively becomes nonrenewable. Even the most important source of energy, the sun, will eventually "burn up." Thus, the definitions of renewable and nonrenewable, as well as their applicability, tend to become less clear and may even break down under close scrutiny. For the sake of convenience, the terms *renewable* and *nonrenewable* are used to simplify relative comparisons between energy sources for discussion in terms of the everyday world we live in.

All levels of the SEEDS program develop the following major concepts.

1. Our earth is a self-contained life-support system composed of a large number of environments, or ecosystems.

2. All living things fit into a complex pattern of interrelationships and interdependencies.

3. People, as well as all other living things, affect their environment and are in turn affected by it.

4. The sun is the earth's most important source of natural energy.

5. People have in the past freed themselves from a way of life dependent on their own muscle-power and the muscle-power of any animals they were fortunate enough to own by using energy from various sources. Modern civilization, and ultimately life itself, will continue only as long as adequate energy sources are maintained.

6. People must change their ways of living to fit changing conditions.

7. The principle of balance is a key to the understanding and wise use of resources.

8. If a natural environment is undisturbed by human beings, it tends to move to a state of equilibrium, or balance.

9. Human beings must disturb the natural balance in order to satisfy their energy needs. However, they should try to establish a new balance, whenever they can. This new balance should be one that supplies their needs while still maintaining the factors that create the needed resources.

10. Individuals should develop sets of values that balance future needs against immediate gains, and social good against private advantage.

Content Summary Chart

	What Is Energy?	Sources of Energy	Conversion of Energy / Forms of Energy	Concerns for the Environment	Wise Use of Energy
Nonrenewable Sources of Energy	General Description • fuel • food • power	History of Energy Sources in Canada • wood • coal • oil • gas • uranium	Combustion → Heat Fission → Heat Distillation → Fuel + By-products Refining → Fuel + By-products	Coal • mines • leaching • combustion Oil • pipelines • tankers • combustion Uranium • mines • reactor • waste	Comparison of supply and demand curves. Definition of *wants* and *needs*. The case for conservation.
Renewable Sources of Energy	Historical Description • chronology of energy sources	Solar Biomass Wind Tidal Geothermal Hydrogen	Radiation → Heat Conduction → Heat Convection → Heat Distillation → Heat Decomposition → Fuel + By-products Mechanical → Electricity	Solar • esthetic Biomass • esthetic Wind • esthetic Tidal • silting	Identification of the role renewable sources of energy can play in the conservation of energy.
Sources of Electrical Energy	Technical Description • force • work • units of energy (joule and watt)	Electricity, the most useful *form* of energy • from hydroelectric *sources* • from thermal-electric *sources*	Perpetual-motion Machines Mechanical → Electricity Combustion → Heat → Mechanical → Electricity Fission → Heat → Mechanical → Electricity	Coal • mines • leaching • combustion Oil • pipelines • tankers • combustion Uranium • mines • reactor • waste Hydroelectric power • dams • towers and wires	Comparison of statistics for projected supply and demand. Doubling effect. Practical and realistic suggestions.

Core Objectives and Skills

Method of Listing Objectives in SEEDS

The pedagogical goal of the SEEDS program is not only to foster the development of understanding and thinking processes with regard to energy and the environment but also to promote attitudinal learnings that will manifest themselves in positive actions, feelings, and values. Both kinds of objectives—cognitive and attitudinal—are included among those listed at the beginning of each activity in the Teacher's Resource Book.

The objectives are listed in as specific a manner as possible, using concrete verbs such as *demonstrate*, *compare*, *contrast*, *classify*, *explain*, *recognize*, *investigate*, and *examine*. There are several reasons for listing the pedagogical objectives so specifically at the beginning of each activity:

1. A clear statement of objectives can help the teacher to assess whatever skills and knowledge the students may already have.

2. Some of the objectives listings may actually be presented to the students themselves rather than serving as teacher information only. Understanding the objectives of a particular activity can help the students to focus upon the desired outcomes of the activity.

3. The listing of educational objectives can help teachers to plan additional learning experiences in conjunction with particular activities, if they wish to do so.

4. The objectives listings are an important aid in evaluation of the students' learning.

The following pages show the core objectives charted by organizing concept.

Core Concepts	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
The Nature of Energy	Define energy by some of its many forms Relate activity and motion to energy Describe an atom	Recall the definition of energy Become familiar with the concept of room temperature Recognize some of the relationships among kinetic energy, mechanical energy, and potential energy Demonstrate that it takes 1 J to lift 100 g 1 m Recognize that power is energy divided by time Recognize that power (in watts) is energy (in joules) divided by time (in seconds)	Explain the failure of perpetual-motion machines on scientific principles Explain and use the unit *joule* Convert Calories to joules Explain the term *watt* Explain the term *power* Convert horsepower to watts
The Importance of Energy from the Sun	Explain how the sun is the source of most of the earth's energy Relate the process by which the sun's energy was converted into the fossil fuel we know as coal	Recall previously-held views of the sun and compare them with modern views of the sun Recall facts about temperature and state of matter in the sun Explain how the sun works Explain how much energy the sun produces	
Sources of Energy	Explain why fuel sources in Canada were first wood, then coal, then petroleum Explain why coal is called a fossil fuel Explain why not all types of coal have the same composition and how this affects fuel quality Explain the theory of the formation of petroleum Explain the difference between uranium and stable materials Tell the story of the uranium cycle from exploration to nuclear reactor	Define solar energy Express the amount of solar energy the earth receives Recall that the earth turns from east to west Recognize that warm air rises and has low pressure Recognize that cool air falls and has high pressure Recognize that high-pressure air moves toward low-pressure air Show that uneven heating of the earth's surface by the sun causes wind Recognize that wind has kinetic energy	Explain the reason for the tides

	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
Distribution and Extraction of Energy Sources	Explain how coal lying near the surface is mined Explain how coal lying far below the surface is mined Explain what happens to raw coal to prepare it for the buyer Locate the coal resources in Canada Explain how petroleum deposits are located by seismic survey Explain how petroleum deposits are reached and how petroleum is brought to the surface Explain how petroleum deposits that lie under the ocean are reached Describe the nature and extent of the oil-sands deposits in Alberta Describe the processes used to mine oil sands Explain how synthetic crude oil is extracted from oil sands Investigate methods of transporting oil from offshore-drilling rigs Explain how oil is transported from the well to the refinery over land and across water Recognize how uranium deposits are located	Discuss problems with capturing the sun's energy Become familiar with a radiometer Demonstrate that the angle of a source of radiant energy to the vanes of a radiometer affects the speed at which the vanes revolve Demonstrate that when the inside of a container is heated by the rays of the sun, the type of cover on the container affects the change in temperature Become familiar with the idea that black surfaces absorb the sun's energy better than white surfaces Demonstrate that when a container is heated by a source of radiant energy placed outside it, the material inside the container affects the change of temperature Recognize that walls and floors absorb energy and radiate it back Become familiar with how solar collectors work Explain how photovoltaic collectors work and how silicon cells are made Recognize how biomass is grown for fuel List some of the components of a horizontal-axis windmill Demonstrate that the angles of the blades of a windmill affect the speed at which the vanes of the windmill revolve Demonstrate that a windmill can be used to store wind energy List four types of horizontal-axis windmills	Explain simply how uranium is extracted and refined List the conditions needed for a hydroelectric site Explain the principle behind a greenhouse Explain how wind energy can be exploited by a wind generator Explain why direct current and storage patterns are associated with wind generators Explain how tides could be exploited for electrical energy in the Bay of Fundy Explain how solar cells could be a source of electrical energy on a large scale Explain how much electrical energy could be produced from our forests Explain what geothermal power is and how relevant it is for Canada Explain what is meant by small-scale hydro

		List three types of vertical-axis windmills State three types of energy storage used by windmills Become familiar with an anemometer Become familiar with the Beaufort scale of winds Rate windspeeds as suitable or unsuitable for windmills	
Energy Conversion	List some of the many by-products from the destructive distillation of coal Explain what distillation means Explain how the principle of distillation can be used to separate liquids with varying condensation temperatures Give a simple explanation of fission Explain how electricity can be produced from uranium	Describe how silicon cells turn the sun's energy into electricity Demonstrate that oxygen helps wood to burn Demonstrate that an aquatic plant exposed to sunlight gives off oxygen Observe and become familiar with dry, or destructive, distillation Recognize the fuels and by-products that can be obtained from biomass Recognize some characteristics of biomass by-products (charcoal, tar, alcohol, and methane) Demonstrate that energy is stored in biomass and that the stored energy can be released by burning the biomass Demonstrate that the energy released from burning biomass can be used to raise the temperature of water Recognize how fuels can be obtained from biomass Find out how much energy (in joules) a model windmill can generate Find out how much power (in watts) a model windmill can generate State the parts of a windmill that make electricity	Describe simple conversions of energy and describe the output of the conversion Give examples of static electricity Connect a simple electric circuit and trace the path of the electricity in that circuit Identify conductors and insulators Show that electricity produces magnetism Show the principle of the electric generator: that an electric current can be produced by coils of wire and magnets Identify the key parts of a generator Explain what a turbine is and how it works Explain how the energy of falling water can be converted into electricity Explain how water stored behind a dam is used to produce electricity Explain how electricity is produced in a thermal-electric plant, whether the fuel is coal, oil, or natural gas Explain fission in simple terms Explain how electricity can be produced from uranium

	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
Uses of Energy and Energy Sources	Define energy by some of its many uses Fit the present widespread use of petroleum for heating and transportation into a historical time frame Account for the changes in the use of coal from 1950 to 1980 Explain how coal is used in the production of steel and electricity Learn that the refinery turns crude-oil fractions from the fractionating tower into more than 1000 different products Learn that natural gas will provide heat, fuel, and the raw material for products in the petrochemical industry Relate the use of petroleum as a source of energy to the larger picture of human history Relate the use of uranium as a source of energy to the larger picture of human history Recall the change in sources of energy used through the centuries	Describe the operation of active and passive solar heating systems State some of the uses of photovoltaic collectors State the fuels that can be obtained from biomass Recognize how biomass can be used for fuels Describe some of the uses of biomass	List ways in which electricity has been applied to home and industry within the past one hundred years Explain why an adequate and continuing supply of electricity is considered to be necessary
Environmental Effects of Extraction, Development, Conversion, and Use of Energy Sources	List some of the hazards of underground mining Explain the effect strip mining can have on the environment Explain the effect underground mining can have on the environment Explain how a planned reclamation can offset the worst effects of strip mining Explain the effect oil-sands extraction has on the environment Explain why oil is spilled on land or on water Explain why oil spills can be damaging to the land and sea environment	List the environmental advantages and disadvantages in capturing solar energy Investigate the consequences of growing biomass for fuel Explain what is meant by the Greenhouse Effect List the environmental advantages and disadvantages in using solar energy Investigate the environmental consequences of using wind energy	List the environmental effects of hydroelectric-generating systems List the environmental effects of thermal-electric generating plants List the environmental effects of the hydroelectric-generating system List the environmental effects of burning fossil fuels in thermal-electric generating plants Explain what is meant by the Greenhouse Effect

	Explain what eventually happens to organic materials, such as oil Name the harmful by-products from the burning of coal and other fossil fuels Explain how acid rain is formed Test the known effects of acid rain List some of the efforts being considered by industry and government to overcome the problem of acid rain Identify the regions in North America most likely to show the effects of acid rain List the advantages of producing electricity by nuclear reactor, and the disadvantages Explain the environmental effects of use of coal, oil, natural gas, and uranium		
Wise Use of Energy and Natural Resources	List some of the beneficial ways radioactivity is being used Describe what effects changes in the future use of coal will have Discuss alternatives to solve the problem of petroleum shortages Recognize new ways in which uranium could be used Explain the benefits of coal, oil, natural gas, and uranium	Give opinions about the role of renewables in our energy crisis Recognize how houses are best situated on building sites in order to use solar energy Explain how biomass from wastes can be used	List advantages the hydroelectric-generating system has over other generating systems Explain why the demand for electricity varies and how the hydroelectric plant can be flexible List advantages of thermal-electric generating plants Explain the meaning of the terms *blackout* and *brownout* Identify ways in which changes could be made by business and industry to conserve electricity Identify ways in which to conserve electricity personally Explain the advantages of small-scale hydro Apply what has been learned about the production of electrical energy to the task of choosing a plan for the provision of electrical energy in the future and weighing the consequences of the plan

The Cognitive Objectives

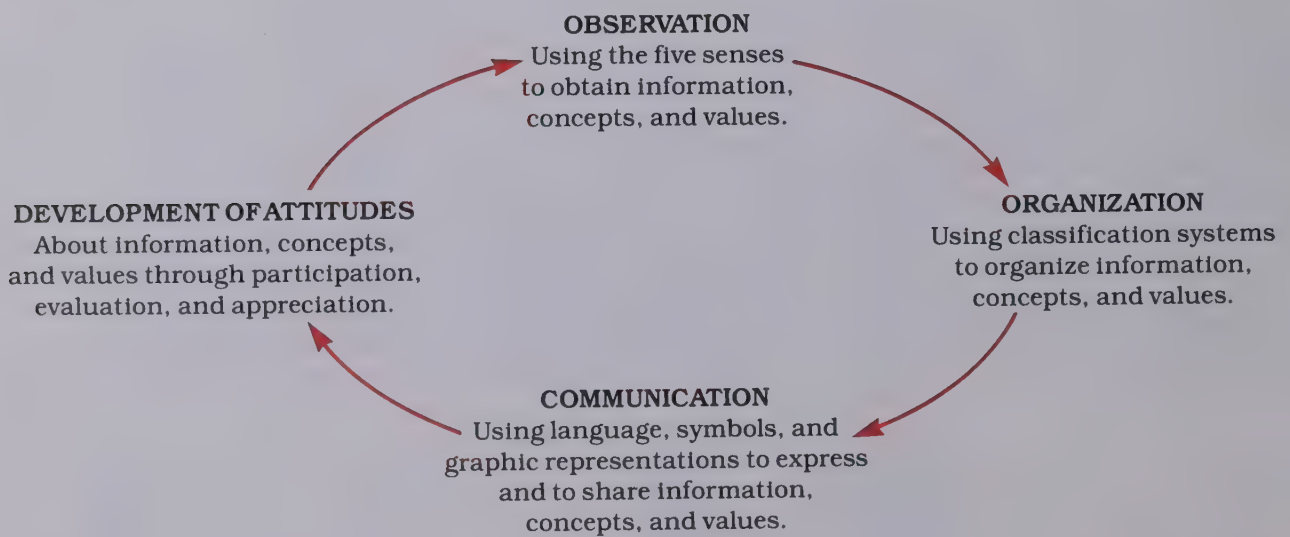
The developers of the SEEDS program have planned the series to assist students in applying rational and scientific thinking processes to energy facts and issues as we know them today. However, it is also hoped that the concepts and thinking skills gained through the series may serve as a springboard for the students in acquiring new energy knowledge and in attacking new energy problems in the future. In our rapidly changing world, students must learn *how to learn*. In order to be effective, well-adjusted members of society, they will need to become lifelong learners.

The following is a partial listing of important thinking and learning skills developed in these levels of the SEEDS program.

- Observing data carefully and accurately.
- Understanding cause and effect relationships.
- Seeing similarities and differences.
- Following order of events; understanding processes.
- Measuring.
- Collecting and organizing information with a specific purpose in mind.
- Making inferences.
- Drawing conclusions.
- Predicting outcomes.
- Evaluating information, ideas, and opinions.
- Finding evidence or proof.
- Reorganizing information into new configurations.
- Presenting information and ideas in clear accurate language, both spoken and written.
- Presenting information in pictorial or graphic form.
- Formulating plans.

Some of the cognitive skills developed in these levels are reflected in the objectives listings found at the beginning of each section of teaching notes in the Teacher's Guides and Teacher's Resource Books. Others, though not specifically listed, can be drawn from the activities themselves to suit individual classes. While there is an emphasis on direct perception of data through observing, listening, and doing, the broader-category skills such as classifying quantities of data, making inferences, and reorganizing information also receive emphasis in these levels.

As the following chart shows, the main learning, thinking, and valuing skills form a circle, each leading to the next. The skills charts on the following pages are organized under these main skills. Specific process skills are charted separately.


OBSERVATION
Using the five senses to obtain information, concepts, and values.
ORGANIZATION
Using classification systems to organize information, concepts, and values.
COMMUNICATION
Using language, symbols, and graphic representations to express and to share information, concepts, and values.
DEVELOPMENT OF ATTITUDES
About information, concepts, and values through participation, evaluation, and appreciation.

Learning, Thinking, and Valuing Skills

Nonrenewable Sources of Energy Renewable Sources of Energy Sources of Electrical Energy

C indicates Core Activity + Student Book page number
X indicates Extension Activity + Teacher's Resource Book page number
E indicates Exercise Sheet + Exercise Sheet number

GENERAL CATEGORIES	SPECIFIC SKILLS	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
OBSERVATION using the five senses to obtain information, concepts, and values	By studying pictorial representations	All C activities Some X activities Some Exercise Sheets	All C activities Some X activities Some Exercise Sheets	All C activities Some X activities Some Exercise Sheets
	By participating in physical activity (roleplaying, manipulating objects, doing experiments, . . .)	C8, C10, C11, C12, C13, C18, C25, C28, C29, C30, C35, C38, C43, C50, C51, C56	C15, C16, C18, C19, C21, C22, C23, C25, C33, C34, C36, C37, C39, C40, C52, C53, C54, C55 X18, X21	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26, C36
	By observing data carefully and accurately (in naturally occurring situations, classroom demonstrations, experiments, . . .)	C8, C10, C11, C12, C13, C18, C25, C28, C29, C30, C35, C38, C43, C50, C51, C56	C15, C16, C18, C19, C21, C22, C23, C33, C34, C36, C37, C40, C53, C54	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26, C37
	By recalling relevant personal experiences and observations	E13	C8 X18	C49, C63 E1
	By reading	All C activities Most X activities All Exercise Sheets	All C activities All X activities All Exercise Sheets	All C activities All X activities All Exercise Sheets
	By doing research	X10, X13, X18, X32, X36, X42	X9, X20, X21, X30, X37 E1, E3, E4	X20, X34, X39, X44
ORGANIZATION using classification systems to organize information, concepts, values	By recognizing similarities and differences: by making comparisons	C8, C30, C32 E10	C11, C12, C13	E3

By recognizing cause-and-effect relationships	C7, C18, C21, C22, C27, C28, C30, C35, C38, C50, C51	C17, C20, C22, C23, C24, C25, C26, C27, C28, C29, C30, C48, C49, C50, C51, C53, C55	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26
By following sequence of events: by recognizing processes	C19, C25, C35, C38, C43	C15, C16, C18, C19, C21, C22, C23, C48, C49, C50, C51	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26
By classifying information under main headings or in categories	C32 E1, E10		E3
By classifying information to show similarities and differences	C32 E1, E7		E3
By recognizing symbolic representations and models	C35, C38, C50, C56	C31, C32, C48, C51, C52, C59	C17, C24
By drawing conclusions	C8, C9, C10, C11, C12, C13, C18, C19, C25, C28, C29, C30, C31, C35, C38, C43, C50, C51	C17, C19, C22, C26, C34, C37, C40, C50, C51, C53, C55 X19 E1	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26, C37
By developing key concepts and appropriate corresponding vocabulary	C9, C14, C15, C16, C17, C18, C19, C20, C21, C22, C25, C28, C32, C35, C38, C43, C54, C56, C57	C11, C12, C13, C29, C31, C32, C42, C43, C44, C45, C46, C48, C49, C50, C51, C52, C53, C54, C55	All C activities
By measuring	C7, C28, C29, C30, C33 E12	C15, C19, C23, C40	C10, C24, C50
By making calculations	C33, C38, C43 X32 E3, E5, E12, E13	C25, C38, C39, C40, C51 X28 E1, E2	C10, C12, C50, C51, C52, C59, C63 E3, E4, E7
By drawing on previous personal experiences and observations in order to make inferences	C7, C8, C9, C10, C11, C12, C18, C19	C8, C51, X30 E3	C63 X11

	By speculating about or inferring probable reasons	C7, C8, C9, C10, C11, C12, C18, C19, C35, C38, C43, C50, C51	C8, C17, C20, C22, C23, C24, C25, C33, C36, C39, C51, C57, C58, C59 X30	C10, C12, C54
	By speculating about or inferring probable cause/effect relationships	C7, C8, C9, C10, C11, C12, C18, C19, C35, C38, C43, C50, C51, C54	C8, C17, C20, C22, C23, C24, C25, C33, C36, C39, C51, C57, C58, C59	C10, C12, C40, C54
	By speculating or making inferences about sequences of events: processes	C18, C19 E4	C8, C51, C57, C58, C59	C63
	By making inferences based on and including (hypothetical) situations	C25, C28, C29, C30	C8, C15, C18, C21, C34, C38, C41, C51, C57 C58, C59	C54, C63 X24 E3, E6
	By speculating about meanings of unfamiliar words	C9		C40
	By predicting probable sequence of events	C7, C53, C60, C62, C63	C24, C57, C58, C59	C24, C63
	By predicting probable outcomes, effects, and/or results	C7, C53, C60, C62, C63 E4	C15, C18, C21, C24, C57, C58, C59 X30	C40
	By proposing appropriate actions based on prediction of outcome	C31, C53, C60, C62, C63	C8 X21, X30	C40 E3
	By predicting possible future developments (in society, . . .)	C7, C53, C60, C62, C63	C8 X21, X30	C40, C63 X11
COMMUNICATION using language, symbols, graphic representations to express and share information, concepts, and values with others	By using oral language in informal discussion	All C activities Most X activities	All C activities Most X activities	All C activities Most X activities
	By using oral language in formal interviews, meetings, speeches, papers	X10, X18, X36	X21	X11, X26

	By completing and/or making charts, diagrams, and graphs	C13 E2, E12, E13	C15, C17, C19, C21, C23, C37, C38, C40, C41, C53	C14, C16, C17, C44, C52 X40 E4
	By indicating and/or interpreting features on a map	E4, E11	E6	C39, C40, C57, C58 X34
	By constructing representational models	C35, C39, C50	C52, C59	C24, C26, C36 X11
	By using written language	All C activities Most X activities Most Exercise Sheets	All C activities Most X activities All Exercise Sheets	All C activities Most X activities All Exercise Sheets
	By preparing oral and/or written summaries, reports, paragraphs, . . .	X10, X13, X18, X36	X9, X11, X30, X37, X41, X42 E2	C63 X11, X26, X34, X39, X40, X43
DEVELOPMENT OF ATTITUDES about information, concepts and values through evaluation, participation, and appreciation	By proposing appropriate actions and solutions (social and values issues)	C21, C60, C62, C63 X23, X36, X41	C62, C63 X11, X21, X30, X41, X42	C27-33, C63 X12, X20, X40, X43
	By evaluating actions and solutions (social and values issues)	C21, C22, C59, C60, C62, C63 X23, X36, X41 E1	C62, C63 X11, X21, X30, X41, X42	C27-33, C63 X12, X20, X40, X43
	By judging worth of consequences	C22, C59, C60, C62, C63 X23, X36, X41	C62, C63 X11, X21, X30, X41, X42	C27-33, C63 X12, X20, X40, X43
	By creating a plan of action	C63 X36, X41 E8	C62, C63 X11, X21, X30, X41, X42	C63 X40, X43
	By applying a plan of action	C63 X36, X41 E8	C63 X41	C63 X40, X43
	By participating in group activities (projects, experiments, meetings, games, . . .)	C63 X18, X23, X36, X41 E8	C15-23, C33-41 X11, X30, X33, X41	C63 X40, X43
	By recognizing personal responsibility	C31, C63 X23, X36, X41	X41, X42	C63 X40, X43

Process Skills Chart C indicates Core Activity/X indicates Extension Activity/E indicates Exercise Sheet

Process Skill	Nonrenewable Sources of Energy	Renewable Sources of Energy	Sources of Electrical Energy
Observing	C8, C10, C11, C12, C13, C18, C25, C28, C29, C30	C15, C17, C19, C22, C34, C36, C40, C53, C54	C10, C12, C14, C15, C17, C19, C20, C22, C24, C26
Classifying	C12, C13, C25, C28, C29 E1		
Quantifying	C7, C28, C29, C30, C33	C15, C19, C23, C40, C53, C54	C10, C24
Communicating	X10, X13, X18, X23, X36	C14-23, C33-41	C37 X12 E6
Inferring and Predicting	C7, C53 E3, E4	C57, C58, C59, C61 X30	C24, C37 E6
Formulating hypotheses	C25, C28, C29, C30	C37, C57, C58, C59, C61	X24 E3, E6
Defining terms	C13, C25, C28, C29, C30, C56	C12, C41	E6
Controlling variables	C13, C18, C25, C29, C30, C35, C38, C45	C39, C53, C54, C57, C58, C59	C10, C15, C16, C17, C19, C20, C21, C24, C26, C36 X24
Interpreting data and results	C7, C8, C10, C11, C12, C13, C23, C25, C28, C29, C30, C35, C38, C43, C53, C60, C62 E13	C9, C10, C11, C12, C15, C17, C19, C23, C24-30, C34, C37, C40, C51, C53, C55, C57, C58, C59, C61	C40, C50, C51, C52, C59, C63 E4, E8
Formulating models, plans	C30, C35, C38	C8, C9, C37, C52-53, C57, C58, C59	C17, C24, C26, C37 E5, E6
Processing data	C7, C12, C13, C23, C25, C28, C29, C30, C53, C60, C62 E3, E4, E5	C9, C10, C11, C12, C15, C17, C19, C23, C26, C34, C37, C40, C51, C53, C55, C61	C29, C30, C33, C50, C51, C52, C59, C63 E4, E5
Identifying problems and Seeking further evidence	Most C activities Most X activities	Most C activities Most X activities	Most C activities Most X activities
Applying discovered knowledge	C59, C60, C62, C63 E15, E16	C24, C25, C34, C37, C39, C40, C41, C43, C53, C55	C10, C12, C29, C30, C33, C35, C37, C40, C57, C58, C59, C60, C61, C62, C63 X26

The Attitudinal Objectives

An attitude may be defined as a predisposition to act in a certain way with regard to objects, persons, and ideas. Attitudes are, of course, related to knowledge. However, they also have a connection with emotions and feelings. The goal of the education system is not to induce all students to adopt exactly the same set of attitudes and values. Rather, it is to help students understand the sources of their values and attitudes, to alert them and to encourage them to act and behave in accordance with their chosen attitudes and values.

With specific reference to energy and environmental education, the SEEDS program attempts to cultivate the following positive attitudes and values.

- Being concerned for other people for the common good.
- Recognizing one's personal responsibility to the society in which one lives.
- Recognizing one's responsibility for one's environment, and attempting to live in harmony with that environment.
- Conserving energy, natural resources, and manufactured products; avoiding waste of any kind as a matter of principle.
- Recognizing the complexity of energy issues and maintaining an open mind with regard to differing viewpoints and new information that one may encounter in the future.

An attitudinal objective in the SEEDS program is usually linked with an opportunity for the students to exhibit behaviors and/or carry out practical actions arising naturally from that objective.

Integrating SEEDS with the Core Curriculum

Relationship of SEEDS to Science, Social Studies, and other Subject Areas

By their very nature, the topics of energy and the environment relate to almost everything we do. Thus, in one sense, the teaching of energy literacy and environmental studies should be thought of as an integral part of the curriculum—to be drawn in whenever appropriate no matter what subject area is officially being considered.

However, in practical terms, following this approach exclusively often results in a somewhat fragmented treatment characterized by serious omissions and undesirable overlaps from one level to another. The SEEDS program, with its comprehensive scope and carefully planned progression of learning experiences, provides a solid foundation and focus for effective energy and environment education as part of a science/social awareness curriculum or on its own as an independent energy curriculum.

The SEEDS program is essentially an interdisciplinary one. In the post-elementary levels, the most prominent subject area identified within it is science/social awareness. The scientific and social aspects of energy and environment issues are closely linked. A serious consideration of these issues requires the information, skills, and attitudes taught in both disciplines.

The practice of centering learning on particular problems—drawing in data and skills from a wide range of disciplines as needed—is widely accepted in educational circles today. The SEEDS program, while drawing most heavily on the subject areas of science and social studies, also brings to bear knowledge and skills from a wide range of other disciplines, including language arts, mathematics, health education, music and art. These other disciplines are integrated in various ways within the Core and Extensions.

Practical Suggestions on Scheduling and Timetables

Each school, and even each class within a school, is different in interests, background, and specific learning needs. It is therefore inappropriate to be prescriptive about the way in which the SEEDS program can best be incorporated into the schedule. However, the program is designed to provide approximately four to six weeks of study.

With regard to timetable adjustments for particular classes, the suggestions given here for activities cannot be prescriptive since situations vary so greatly. As a rule, it is probably best to schedule a definite amount of time per day or week for the SEEDS program, while still allowing for some flexibility, if possible. If the actual amount of time remains flexible, the students will almost always have the satisfaction of completing investigations or projects without being interrupted. Sometimes a longer period can be crucial to the gaining of a particular concept or insight.

At the beginning of each activity in the SEEDS Teacher's Resource Book, the teacher is informed of the length of time likely to be required not only by the setting up but also by the duration of the activity. Generally, the time suggested for Activities increases gradually from level to level within the series.

The following are some overall considerations and principles that administrators and teachers may wish to keep in mind as they plan their timetables with reference to the SEEDS series.

1. One possibility for the SEEDS program is that it be scheduled for periods usually given to science and social studies. The time of day is not crucial in many cases.

2. The SEEDS program does not require much use of special rooms or special facilities within the school. Since an average science classroom with the usual equipment will suffice for most of the activities at the upper levels, the need for complicated meshing of schedules among teachers is kept to a minimum.

3. In some cases it may be helpful to appoint a SEEDS program coordinator for the school. (Such a person could not only assist teachers in planning timetables, but could also perform such valuable services as investigating local community problems and resources with regard to energy and the environment.)

4. Team teaching of the SEEDS program or parts of it may be worth considering as a possibility. In this way teachers with special knowledge and capabilities in the area of energy and environment education could share their expertise with more than one class within the school. Science and social studies teachers could profit from a combined approach to the energy issues.

Teaching Strategies Used to Present and Develop Concepts

The "Guided Discovery" Approach

Some science and social studies curricula strongly emphasize processes of inquiry such as observing, describing, measuring, classifying, inferring, and predicting. Others are based on the idea that science and social studies are essentially organized bodies of subject matter. In actual fact, both *processes* and *subject matter* are important. There is a place in the study of science and social studies for both experimentation and reading. Students cannot learn everything from experimentation and firsthand experience. On the other hand, it is important for students to practice processes of inquiry and develop the attitudes of scientifically-minded persons. Scientific processes and attitudes can be transferred to other subject areas, and are valuable as a basis for learning of any kind.

The SEEDS program uses both "telling" and discovery as strategies for the presentation and development of concepts—the "guided discovery" approach. The strategy used in a particular core depends upon such factors as the subject matter under consideration, the probable availability of suitable equipment, and the relative maturity of the students. However, there is in general a stronger emphasis on the discovery approach. It should also be noted that the "discovery approach" may take either an *inductive* or a *deductive* form.

In the inductive form or pattern of discovery, students might make certain observations, form hypotheses based on these observations, and then experiment to test the validity of their hypotheses. In the deductive form, on the other hand, the students might be presented with a generalization first (rather than with a set of observations). They would deduce certain consequences from this generalization. Then they would conduct a suitable experiment and compare its results with the consequences that they had previously deduced. Students might also suggest experiments themselves, following similar methods of investigation.

The following are some practical guidelines for the classroom implementation of the experiments, demonstrations, investigations, and other "guided discovery" experiences suggested in the SEEDS program.

1. As far as possible, allow the students to plan and organize the experiments, making their own predictions about what might happen and drawing their own conclusions about the results.

2. Keep experiments and demonstrations simple. Most of the materials suggested in the SEEDS Teacher's Resource Books are readily obtainable at home or at school. Teachers and/or students should have little difficulty assembling the required materials.

3. Make sure that the students keep the purpose of an experiment firmly in mind as they are conducting it. It may sometimes be advisable to write the purpose on the board for ready reference.

4. It is often helpful to have the students keep a written record, a graph, or a chart of the experiment as it is being conducted. Small drawings of things being observed are also a good way to record information.

5. Whenever possible, allow the students to manipulate the apparatus themselves, even if they only repeat the experiment or demonstration after you have done it once.

6. Take advantage of situations in which experiments do not follow predicted paths. If this happens, a *real* problem has arisen. it is not in any sense a "staged" problem. As a result, the students are challenged to think more deeply and plan more wisely. Thus, greater learning may actually take place.

7. Guide the students to apply information gained from experimentation to real-life situations. Your own local situation will suggest ways of doing this.

8. In your preparation for teaching a particular SEEDS chapter, you may wish to carry out a "dry run" of any experiments and demonstrations connected with the chapter. In this way you can solve any unforeseen problems beforehand. You might like to involve older students who would be interested in helping you do this.

9. You may wish to consider the possibility of filming or video-taping some of the experiments and demonstrations. Students may be interested in making films of themselves performing experiments. Such films could be shown to other classes or to parents on a "parents' day" at school.

Questioning and Class Discussion

Skilful questioning plays an important part in the development of concepts and cognitive skills in the SEEDS program. The following are some of the characteristics of the suggested questions for students found within the Student Book and Teacher's Resource Book.

1. The questions are clear and specific.

2. They are arranged in carefully planned sequences. They are not asked at random, but in integrated series in order to accomplish specific purposes. Sometimes the purpose of a question series is to refine the students' understanding of certain concepts. Sometimes the goal is to identify and/or review important facts. At other times the purpose of the questioning is to have students apply their knowledge to real or hypothetical problems.

3. There is a balance between fact-oriented questions and questions requiring thoughtful answers. Questions requiring thoughtful answers in the SEEDS program encourage the students to use a variety of cognitive processes, including:

- recalling data;
- classifying data;
- comparing and contrasting data;
- showing cause and effect relationships;
- giving examples and illustrations;
- making and evaluating decisions; and
- analyzing or synthesizing facts.

Group Activities

Many of the learning experiences suggested for the SEEDS program involve the students working in groups. This is especially true of the Extension activities that follow the basic Core material. Small-group activity may sometimes be more difficult to organize and oversee than whole-class instructions. However, group work does have certain distinct advantages:

1. Group activities give students a measure of self-determination and freedom.

2. The development of critical thinking is encouraged by group work. The group must propose various courses of action, rejecting some and choosing others.

3. Working in groups develops the students' organizational abilities.

4. The students practice communication skills, and become aware of effective group processes.

5. Group work fosters a spirit of active cooperation, in which a common goal and group welfare are both perceived as important.

6. Students gain new insights into the talents and abilities of their classmates.

7. Group work is a strategy for making learning more meaningful and immediate, since a group project usually involves the application or transfer of learning that has previously taken place.

Community-based Activities

Two obvious ways of making use of community resources are: inviting visitors from the community to give talks or demonstrations, and taking the students on field trips into the community.

Your school may already have a list of suitable resource persons with differing areas of expertise. Sometimes the students themselves may be able to suggest names of possible visitors. Keep the following suggested guidelines in mind when arranging for a visit by a resource person.

1. Find out ahead of time what specific contribution the visitor can make.

2. Discuss with the visitor your reasons for inviting him or her, the grade level of the students and a time that would be mutually convenient. It might be wise to suggest to the visitor approximately how long you would like his or her presentation to take.

3. Make sure that the students have the purpose of the visit clearly in mind ahead of time.

4. Make plans with the students regarding how they can get the most out of the visit. It is often helpful to discuss what kinds of questions they might want to ask.

5. After the visit, discuss with the students what they gained from it. Clear up any misconceptions that they may have.

6. Arrange with the students how they may thank the visitor. An individual or group might be appointed to write a short thank-you note. The class might send the visitor projects or class presentations made as a result of the visit. If appropriate, you or one of the students might even telephone the visitor to thank him or her.

The following suggestions should help you to plan interesting, valuable and trouble-free field trips.

1. Have a real reason for making the trip. The trip should be an integral part of the ongoing study, and its purpose should be clearly understood by the students.

2. Make a "dry run" of the trip yourself first in order to determine realistic objectives and identify any problems that could arise.

3. Make the necessary arrangements with: school authorities, owners or authorities in places you intend to visit, parents (secure written consent from parent or guardian for each student), and any individuals who will be helping you with transportation or supervision of the students.

4. Advise the students (and perhaps parents as well) of suitable clothing for the trip.

5. If the students are to make notes, make sure that they take writing materials with them.

6. If necessary, discuss with the class suitable conduct and standards of courtesy that should be observed during the field trip. Allow the students themselves to suggest these.

7. If the group is large, you may wish to divide the students into "teams." Each team could have a leader. The leader might be an older student, a parent, or another teacher who has agreed to help you.

8. If desired, each "team" might be given a specific assignment with regard to things to watch for or information to be gathered during the trip.

9. Don't plan for the students to see too much in one trip. Make sure that you are not rushing them through the trip. This is especially important with younger students.

10. During the field trip, encourage the students to *observe* carefully and accurately.

11. If brochures or maps or other explanatory materials are available at the place you are visiting, obtain some for later classroom use.

12. Classroom follow-up can take many forms. There should almost certainly be a classroom discussion of the experience and how well it achieved the predetermined purpose. Other possible forms of follow-up would include: oral and/or written reports, field-trip booklets or diaries, posters, murals, more comprehensive, illustrated class projects, and repeat visits to investigate aspects the students feel they did not see thoroughly enough on the first visit.

Certain cautions are in order with respect to having students make field trips into natural environments. Such environments can be much more easily damaged than we often realize, as pointed out in the following excerpt from *Nuffield Junior Science, Teacher's Guide 1*, published for the Nuffield Foundation by William Collins Sons & Co. Ltd., London, 1967, p. 268.

"Apart from the dangers created by collecting there is the possibility of damage from thirty to forty pairs of feet. This is generally less harmful to plant life than animal.

"Recently, a study was made of the effect of a group of twenty people walking through a stream with a rocky bottom. The disturbance of the stones by feet resulted in a large haul of animals, mainly stonefly and mayfly nymphs, being caught in nets placed further down the stream. Examination of these disturbed areas showed that they had a reduced population of animals compared to undisturbed areas.

"Disturbance of stones in terrestrial habitats can result in the destruction of microhabitats exposing the animals to dangers of desiccation or predation. All stones turned over on the sea shore, land, ponds, or streams should be replaced as nearly as possible in their original position.

"Damage to vegetation may be slight, but for a small group of flowering plants it may mean that flowering cannot take place that season, so there will be a loss of seed this year. Clearly, if this were repeated annually some plants in the area would eventually be destroyed.

"Even slight damage to vegetation may be sufficient to indicate the presence of a nesting bird to a natural predator or suggest its presence to other humans. When we observe nesting birds we must take care not to expose the nest in any way. We must strike a balance between the need to observe and the risks of desertion and predation.

"Occasionally, the interest of the [students] may, as in a case we know of, when a group of ten-year-old boys wanted to band birds, have to be opposed because they would contravene the laws of the land. It is illegal to capture a bird for observation or banding unless the catcher has a licence to do so. Any such work would have to be done by a licensed specialist who could be called upon to help or take the [students] on a visit to a local bird observatory.

"One bird observatory run by a group of amateur ornithologists arranges transport facilities for visiting school parties, and its members demonstrate the varying techniques used. They are most helpful to parties wishing to do general field work in the area surrounding the observatory, but do not allow visits to the rocky shore and sand dune areas during the breeding season of ground nesting birds. The use of local experts in this way can be of great value both to the teacher and the class. Information about the distribution of rare plants and animals and the areas in which they occur is valuable in deciding suitable areas in which the pupils can work. Clearly such areas should be avoided for general field work."

Review and Evaluation

The progression and continuity of the SEEDS program follow a spiral pattern. It is often impossible to present an important concept fully when first introduced at the primary levels because of the relative immaturity of the students. However, in the SEEDS program, that same concept is presented again within the level, and also from level to level. Each time the concept is presented, the context is somewhat different and the meaning is more completely developed: such an approach helps the students gain an increasing understanding of a core of essential ideas. The use of the spiral approach also constitutes a built-in review mechanism within the program.

In spite of the continual recycling of concepts, you may find on occasion that certain facts and ideas need to be reviewed or retaught.

Evaluation of student learning can take several forms. Particularly applicable to the SEEDS program is the observation of pupil behavior with reference to specific stated objectives.

Since the learning objectives for each section of the SEEDS program are specifically stated at the beginning of that section in the Teacher's Guide or Teacher's Resource Book, they provide a basis for evaluation. Other important educational goals may be found in the discussion of cognitive and attitudinal objectives. Each student should be observed over a period of time, and those observations should be recorded in writing periodically. Such accumulated written observations can serve as a valuable basis upon which to form an opinion about individual pupil learning.

One should be careful to keep individual differences in mind. What might represent real progress for one student might be less important for another.

Also, it is not enough to be satisfied with mere verbal performance. The emergence of new behaviors in the classroom also indicates that learning has taken place. The following are some examples of acquired behaviors:

1. Showing originality and resourcefulness in research.

2. Finding solutions through reading.

3. Participating in experimentation.

4. Engaging in investigative activities on one's own initiative.

5. Beginning to expect and look for predictability and order in relation to natural phenomena.

6. Distinguishing fact from fancy.

7. Questioning and evaluating sources of information.

8. Withholding judgment until sufficient evidence is available.

9. Demonstrating the ability to be either a leader or a follower, depending on the situation.

10. Showing by actions that one understands and sympathizes with the feelings of other people.

Student questions in the Student Book and in the Teacher's Resource Book are of several different types, concentrating not only on subject matter but also on thinking skills such as identifying reasons, understanding processes, and making comparisons. These questions provide another instrument for assessing the day-to-day acquisition of learning of the students.

Materials

Materials Found Within the Program Itself

As stated earlier, the SEEDS program provides a full range of materials for each post-elementary level.

1. A comprehensive Teacher's Resource Book with Professional Reference Guide.

2. A Student Book that has been designed to stimulate the students' curiosity about energy and the world around them.

3. A series of reproducible Exercise Sheets for additional written work (found at the end of the Teacher's Resource Book).

Complete and specific instructions for the use of the materials will be found as one progresses through the numbered chapters in the Teacher's Resource Book.

The use of the Student Book, particularly, is quite flexible. Sometimes it is used to introduce a concept. Sometimes it is used as a focus for group work. At other times the Student Book is used to summarize or review what has gone before.

The students are not to write in their Student Books. Students are encouraged to keep an activity notebook in which to record their observations and conclusions. The reproducible Exercise Sheets for each level provide for additional reinforcement of and response to what has been learned.

The Professional Reference Guide provides helpful teaching strategies, as well as background information about the program, and the kind of pedagogy it is based on.

Concrete Materials to Accompany the Program

A recent survey of science teachers revealed that one of the greatest problems they experienced was the difficulty of obtaining materials for scientific experiments and demonstrations. The materials required for experiments and demonstrations in the SEEDS program have been deliberately kept very simple. For the most part, at the upper levels, they are the kinds of things that can be easily found in the average science classroom.

In addition to the materials directly required for experiments and demonstrations, the teacher of the SEEDS program would be well advised to assemble as many other related "real things" as possible. These might include: classroom plants of different kinds, a rock collection, a shell collection, a leaf collection, samples of various kinds of wood, samples of fossil fuels, objects made from fossil fuels, a terrarium, an aquarium, and so on. Of course, many science classrooms already have an abundance of this kind of material.

Some of the many advantages of realia in the classroom are that they:

1. Introduce a variety of stimuli, encouraging the students to use all of their senses—seeing, hearing, touching, tasting, and smelling.
2. Increase and sustain the students' attention.
3. Bring into the classroom events and phenomena that would otherwise remain remote in place or time.
4. Illustrate applications of abstract concepts, and increase their meaningfulness for the students.
5. Can promote a spirit of cooperation and develop a sense of responsibility in the students especially if their help is enlisted in assembling the objects and caring for them.

Printed Materials as a Resource for the SEEDS Program

A wide selection of books, pamphlets, pictures, and other printed reference materials related to energy and the environment should be made easily available to the students if at all possible. A comprehensive collection of such material will help to meet the special needs of individuals. For example, a student might have poor reading ability, but be very much interested in finding out more about coal mining. An "easy" library book on the subject can meet this special need. Another student might be putting together a report on a current energy issue. A readily available and up-to-date collection of newspaper clippings can be of great help to this student.

A wide selection of materials allows students to work independently or in small groups, either to complete projects suggested with the SEEDS program or perhaps to carry out their own investigations on matters of particular regional interest. An abundance of available material also encourages students to maintain the valuable habit of consulting a variety of sources.

Printed materials that would be particularly useful to the students working on the upper levels of the SEEDS program include:

1. One or more sets of encyclopedias, preferably well-illustrated.
2. Nonfiction, science-oriented books written for the general public.
3. Atlases and maps.
4. Dictionaries.
5. National almanacs; world almanacs.
6. Leaflets, pamphlets, bulletins, brochures, calendars, charts, posters—often found as free or inexpensive materials from museums, historical societies, conservation organizations, commercial companies and so on.
7. Pictures, photographs, postcards.
8. Magazines (some adult-level technical magazines may also be suitable as reference for interested students).

9. Relevant newspaper clippings.

10. Locally produced materials—reports on use of energy in your community, guides to wildlife identification in local parks, local histories, and so on.

If you have access to a large central library, you might take out a number of books relating to particular subjects in the SEEDS program. Many communities also have travelling libraries. With advance planning, a selection of appropriate books could be on hand when needed. Sometimes books and other materials can be borrowed from Departments of Education.

A teacher who develops a "collector's eye" can, in the course of everyday life, amass an amazing amount of free and inexpensive printed material suitable for use in the classroom. Students can assist in finding and organizing such material. For example, they could write letters requesting free government publications, booklets published by various industries, and so on. With teacher guidance, they could also develop an efficient filing system for the collected material.

The following are a few suggestions for the use of supplementary printed materials with the students.

1. Select books and other materials with care. Try to make sure that they give accurate information. If discrepancies arise between books, take advantage of the situation to point out that it is wise to evaluate sources carefully and consult a variety of sources whenever possible.

2. Whenever possible, use reference reading materials after the students have had firsthand experience or have read and discussed the material in the Student Book. The reference materials will help them pursue special interests or answer new questions raised in their minds.

3. Generally, have the students read with specific purposes in mind. Help them to be selective, recording and reporting only the information that is appropriate to their particular investigation or project.

4. Be sure students know how to use tables of contents, indexes, glossaries, and other reference tools, properly.

Choosing Supplementary Audio-visual Materials

The SEEDS program offers a filmstrip for each elementary level, and also concept framework filmstrips covering Levels 1–3 and Levels 4–6. At the post-elementary levels, other useful filmstrips, as well as slide presentations and motion pictures, are available from a variety of sources. However, these do need to be carefully chosen if they are to achieve the desired objectives. They should be appropriate to the ages of the students. Any supplementary audio-visuals should also be accurate and should present sufficient data for the development of concepts. There should be a balanced presentation of data and viewpoints. One should watch this particularly with audio-visuals produced by special-interest groups such as commercial companies or advocates of very different alternative lifestyles.

If you have specialized knowledge in a particular area or access to special equipment or settings, you may wish to consider making some audio-visuals of your own. For example, if you are able to visit a site where oil sands are being mined, you might wish to make a slide presentation or filmstrip of the process. Other teachers in your school may have personal slide collections or movie films that could prove useful. Students themselves may be able to participate in photography and film-making.

Using Audio-visual Materials

The following are some general guidelines for the use of filmstrips and other audio-visuals with the SEEDS program:

1. Always store filmstrips at room temperature. If filmstrips are used when they are hot, they will stretch. If they are cold, they will become brittle and break.

2. Always preview the audio-visual before using it with the class. You might do this alone, with other teachers, or perhaps with a small committee of students. Plan how the audio-visual will be used, referring to the film guide if there is one.

3. Prepare the class. Discuss with them the reasons for seeing the film. Give them some main points to watch for, helping the students to separate the important from the unimportant. Present any difficult vocabulary used in the film if you feel this is necessary. List any questions that the students would like to have answered through the viewing of the film.

4. After the students have seen the film, discuss it with them to see what they have learned from it. Discuss whether the film answered the questions that the students posed beforehand.

5. Do not expect too much from one showing of a film. At least two showings of a particular film are often advisable. You may wish to show the film without the sound the second time. This will allow you and the students to discuss the film as it progresses. It can also be a technique for evaluating learning if you ask questions or have the students supply the commentary.

6. In order to involve the students even more, you might like to have them record, in groups, their own version of the audio portion of filmstrips.

7. Sometimes a follow-up activity may be appropriate. This might take the form of a written or oral report, creative writing, research, preparation of pictures or charts, role-playing, or dramatization.

Notes

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